S. A. E. JOURNAL

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W. G. Wall, *President* Coker F. Clarkson, *Secretary* C. B. Whittelsey, *Treasurer*

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Los Angeles Aeronautic Meeting

Five Sessions and Twelve Papers Scheduled for Meeting, Sept. 11 and 12, During National Air Races

FOUR technical sessions for the discussion of aeronautic transportation and design, a standardization conference, and a joint banquet of the Society with the National Air Race Association have been arranged for the Western Aeronautic Meeting by the Aeronautic Meeting Committee under the chairmanship of Glenn L. Martin. This event, which is only one of three National Aeronautic Meetings scheduled for the coming season, is expected to be one of the most important aeronautic events ever held by the Society. The selection of Los Angeles as the place of this meeting emphasizes the position that the West Coast has taken in aeronautic activities.

Passenger Transportation

Because of the large number of aircraft-operating lines on the West Coast, the Passenger Transportation Session will perhaps be the most interesting of the four technical sessions. Papers on the subject are to be presented by Harris M. Hanshue, of the Western Air Express Co., and by A. K. Humphries, vice-president and general manager of the Pacific Air Transport Co. The relation by these speakers of the experience gained by their companies in the transportation of passengers should institute a new era in aeronautic papers. The future of air transportation from a meteorological viewpoint will be discussed by Dr. Carl G. Rossby and Horace R. Byers, of the Daniel Guggenheim Foundation for the Promotion of Aeronautics. There is no question that the weather factor is a most important one in passenger transportation, and fundamental information on this subject will be of great value to the aeronautic industry.

Metal Construction

Two papers dealing with metal construction are to be presented at the evening session on Sept. 11. The first is by Lieut.-Commander L. B. Richardson, of the Naval Air Station at San Diego, and the second by H. V. Thaden, vice-president of the Thaden Metal Aircraft Corp. Mr. Thaden's paper deals with the design of metal aircraft, while the subject of Commander Richardson's paper is The Maintenance of Duralumin Used in Naval Aircraft.

A third paper will be presented at this session by George H. Prudden, managing director of the Prudden-San Diego Airplane Co., on Metal Airplane Construction Economics.

Two papers discussing instrumentation will be presented at the Wednesday morning session on Sept. 12. The subject of the first, by C. S. Moody, of the Pacific Scientific Co., is The Latest Types of Aeronautic Instruments. In the second paper Dr. Clark Millikan will describe the new aeronautic laboratory of the California Institute of Technology, funds for the equipment of which were provided by the Daniel Guggenheim Foundation.

THE PROGRAM

Tuesday, Sept. 11

9:30 a. m.—Passenger Transportation Session: Papers by Harris M. Hanshue, A. K. Humphries, Dr. C. G. Rossby and Horace R. Byers.

2:00 p. m.—Standards Conference: Discussion of Commercial Aircraft Standardization.

8:00 p. m.—Metal Construction Session: Papers by George H. Prudden, Lieut-Com. L. B. Richardson and H. V. Thaden.

Wednesday, Sept. 12

9:30 a. m. — Instrument Session: Papers by W. P. Balderston, Dr. Clark Millikan and Commander E. E. Wilson.

8:00 p. m.—Design Session: Papers by Mac Short, G. F. Vultee and Waldo N. Waterman.

Saturday, Sept. 15

Joint National Aeronautic Association and Society Banquet.

General Design

Mac Short, chief engineer of the Stearman Aircraft Co., will discuss the subject indicated by the title of his paper, The Design and Production of Commercial Aircraft, at the Wednesday evening session. G. F. Vultee, chief engineer of the Lockheed Aircraft Co., is to give a paper on Methods and Materials Employed in the Fabrication of the Lockheed Vega Model, and Waldo N. Waterman, experimental engineer of the Bach Aircraft Co., will discuss the subject, Air Transportation Needs as Analyzed in Designing the Bach Air Yacht.

A fourth paper at this session will be by Commander E. E. Wilson, who will discuss The Influence of Battle Tactics on Design Technique. Commander Wilson is chief of staff to the Commander of the Aircraft Squadrons with the Battle Fleet.

From the foregoing outline of the technical program, it will be appreciated that members who are privileged to attend the sessions at the Los Angeles meeting will obtain a great deal of valuable aeronautical material, besides having an opportunity to take part in a discussion of subjects that are of vital interest in the industry at this time.

Joint Banquet

On Saturday evening, Sept. 15, the National Aeronautic Association and the Society will hold a joint banquet at the Ambassador Hotel. The program for this will be announced in a special bulletin to be issued by the local S. A. E. Committee at Los Angeles.

Standardization

No doubt the most vital need of the aeronautic industry today is the commercial standardization of materials and parts. Recognizing this, the S. A. E. Aeronautic Standards Committee, under the chairmanship of the Hon.

Meetings Calendar

Western Aeronautic Meeting
Sept. 11 and 12, 1928
Biltmore Hotel, Los Angeles

Transportation Meeting
Oct. 17 to 19, 1928
The Robert Treat, Newark, N. J.

Production Meeting
Nov. 22 and 23, 1928
Book-Cadillac Hotel, Detroit

Eastern Aeronautic Meeting
Dec. 6 and 7, 1928
Chicago

Aeronautic Operation Meeting
January, 1929
New York City

Annual Dinner
Jan. 10, 1929
New York City

Annual Meeting
Jan. 15 to 18, 1929
Book-Cadillac Hotel, Detroit

Chicago Section Meeting—Sept. 4, 1928
Aircraft in Commerce—Lester D. Seymour, assistant general manager and chief engineer, National Air Transport, Inc.
Maintenance of Aircraft and Aircraft Engines—E. P. Lott, manager of operations, National Air Transport, Inc.

Cleveland Section Meeting—Sept. 29, 1928
Outing

Milwaukee Section Meeting—Sept. 12, 1928
Summer Frolic—Golf, Horseshoes and Other Sports Followed by Dinner and Entertainment.

Washington Section Meeting—Sept. 13, 1928
Brakes—Speaker to be announced.

Edward P. Warner, has initiated a comprehensive program of standardization. At a conference on Tuesday afternoon the existing specifications and specifications now being formulated will be considered. At this conference there will also be presented papers in which the authors will discuss what the aeronautic industry has to learn from the standardization accomplished by the automobile industry and the needs of the aeronautic industry for standardization.

Headquarters Hotel

All the technical sessions and meetings are to be held at the Los Angeles-Biltmore, with the exception of the banquet, which will be at the Ambassador Hotel. Information regarding all the S. A. E. activities will be available at an S. A. E. registration desk at the Los Angeles-Biltmore. Members who are contemplating attending the Los Angeles meeting should make hotel reservations immediately, as the city will be crowded by attendants at the air races. Members who are unable to secure reservations at the headquarters hotel should be able to obtain accommodations at one of the following: Ambassador, Huntington, Mayfair, Van Nuys, Hayward, Rosslyn, Alexandria, and the Gates. Rates at the Los Angeles-Biltmore range from $5 to $8 per day for single rooms. The other hotels, in the order named, charge from $6 to $1.50 for a single room and bath.

Railroad Fares

Summer-tourist railroad tickets are available until Sept. 30, good for the return trip until Oct. 31, with the privilege of stopovers at any points en route. The cost of such tickets to Los Angeles or San Francisco, going by the Santa Fe route and returning by the same or any other direct line, is: From New York City, $138.32; from Detroit, $101.70; from Chicago, $90.30. The cost of a lower berth in each direction is: New York to Los Angeles, $32.63; Chicago to Los Angeles, $23.63.

As an example of the daily train service, members can leave New York City at 5:30 p.m., Sept. 3 and arrive in Los Angeles at 9:15 a.m., Sept. 7.

The Committees

Members responsible for the Los Angeles meeting are Glenn L. Martin, chairman; Ethelbert Favary, E. D. Osborn, Edward P. Warner and Capt. L. M. Woolson, constituting the Aeronautic Meeting Technical Program Committee. A local committee that has been appointed consists of Ethelbert Favary, chairman; Donald Hall, Charles Lienesch and William Waterman, W. H. Fairbanks, F. C. Patton, J. J. Canavan, E. B. Moore, and L. M. Griffith.

The Exposition

In addition to the National Air Races, members will have an opportunity to attend the Aeronautical Exposition at Los Angeles. It is understood that almost every manufacturer of aircraft and aircraft parts and accessories in the Country will have an exhibit at this exposition. The California Air Race Association reports that more than 3200 applications for entry blanks have been received for the races. One hundred and sixty-five applicants have signified their desire to enter the Transcontinental Non-Stop Flight, as contrasted with only 13 applications in 1927 when the meeting was held at Seattle.

Transportation Meeting

Seven Technical Sessions and Banquet Scheduled for Oct. 17-19 at Newark

THE program for the National Transportation Meeting, to be held in Newark, N. J., is taking final form in the hands of the committee under the chairmanship of F. C. Horner. Sessions will be held on the morning and afternoon of each of the three days, Oct. 17 to 19, as well as a special session for the discussion of operation and maintenance principles on the first evening and a Transportation Banquet on the second evening.

An inspection trip will also be made on the morning of Saturday, Oct. 20, to the Holland Tunnel, where the plant and traffic-control methods will be studied.

An entire session is to be devoted to the discussion of store-door delivery, a subject that is of great importance to everyone interested in automotive transportation. The principal paper will be presented by R. A. C. Henry, Director of the Bureau of Economics of the Canadian National Railways. The title of his paper is Canadian Store-Door Delivery of Today. Following Mr. Henry's paper, prepared discussion will be submitted by a number of merchants and railroad authorities.

Closely allied with store-door delivery is the subject of six-wheeled vehicles and legislation pertaining to their use. Ethelbert Favary, who is connected with the Moreland Motor Truck Co., of Los Angeles, in the development of six-wheel vehicles and has taken a prominent part on the West Coast in discussions as to the right to operate them on public highways, will give a paper on Highway Legislation and the Six-Wheel Truck. A companion paper, discussing the subject from the viewpoint of highway development, will follow this paper. The committee in charge of the meeting plans to invite representatives of State highway commissions to attend this session and state their views.

The West Coast will be represented in a session devoted to three service problems in motor transport. These problems, indicated by the titles: Education on and Prevention of Accidents; Is It Cheaper to Farm-Out Work or Maintain Your Own Repair Shop? and When Is the Proper Time to Trade-In the Old Truck?, will be discussed by E. C. Wood, of the Pacific Gas & Electric Co. Mr. Wood is vice-chairman of the S. A. E. Operation and Maintenance Committee and chairman of the Subcommittee on Air-Cleaners, Oil-Filters and Shock-Absorbers.

Members who heard Mr. Wood at the Transportation Meeting in Chicago last year will look forward to this session. The East has a great deal to learn from the West Coast in the matter of truck operation and maintenance, and the Transportation Meetings are therefore serving a common good in bringing the East and the West together for the discussion of common subjects.

Chicago Aeronautic Meeting

THE Aeronautic Meeting Technical Program Committee is developing a comprehensive program for a two-day Aeronautic Meeting in Chicago during the National Aeronautic Exposition, the dates selected for the Society meeting being Dec. 6 and 7. More than 50 subjects for papers are being considered by the Committee, with a view to deciding on a technical program that will warrant the attendance of every aeronautical engineer in the Country. Only subjects of vital importance to the industry at this time will be listed, and leading authorities on each subject will be included in the program.

Chronicle and Comment

Committee on Divisional Reorganization

IN compliance with the request made at a meeting of members of the Constitution Committee and other interested members of the Society, at the Summer Meeting in Quebec, President Wall and First Vice-President Strickland have asked a number of members to serve on a special committee to study the question of "divisional reorganization" of the Society. Back of this action lies the demand that has been made from time to time for specific representation on the Council of fields or phases of automotive engineering work, such as fleet operation, maintenance and service; body engineering; and production engineering, that are not specifically represented under the present organization of the officership and Council, and as a result of which fact it has been stated that there is an inconsistency in the officer and committee line-up in the Society.

Those who have been asked to serve on this special Divisional Reorganization Committee are:

F. E. Moskovics, *Chairman*

Constitution Committee Chairmen

V. G. Apple	Sections Committee Chairman
W. L. Batt	Finance Committee Chairman
E. P. Blanchard	Production and Production-Meeting Committees Chairman
F. F. Chandler	Former Member Constitution Committee
J. C. Chase	Constitution Committee
Coker F. Clarkson	General Manager
Howard E. Coffin	Past-President and Constitution Committee
H. M. Crane	Past-President and Standards Committee Chairman
W. T. Fishleigh	Past-Chairman Detroit Section and Nominee for Councilor
H. L. Horning	Past-President
John H. Hunt	Past-President
Charles F. Kettering	Past-President
R. E. Plimpton	Operation and Maintenance Committee Chairman
Norman G. Shidle	Past-Chairman Pennsylvania Section
W. R. Strickland	Nominee for President
W. G. Wall	President
E. P. Warner	Nominee for First Vice-President
J. F. Winchester	Meetings and Research Committees

A Wealth of Material

ONE of the evidences of the great activity in motor-vehicle and aeronautic engineering fields at the present time is the increased volume of papers and discussion received by the editorial department of THE JOURNAL. So much good material has been available that the problem has been to find space for all that should be published, without making each issue of THE JOURNAL too large. More papers and discussion are now in hand than can be published in the next two issues. With the opening of next season's National meetings with the first Aeronautic Sessions in Los Angeles in September, and the resumption in October of the Section meetings, which will start a flow of new papers and discussion, it will be possible to print only papers of high merit that deal with timely subjects.

This situation may be expected to create competition among the Sections to secure the presentation at their monthly meetings of papers of such excellence that they will find a place in THE JOURNAL in company with the best papers given at the National meetings.

A number of new interests in the Society are pressing for representation through papers and discussion in the official organ of the Society. These, in addition to the extraordinary development of interest in aeronautics, include increased activity in motorcoach engineering, radical ideas that are coming forward in automobile engineering, the growing importance of fleet operation and maintenance, and the need for giving attention to the problems of production engineering.

Whereas several years ago a single day's sessions sufficed for an annual Aeronautic Meeting of the Society, three National Aeronautic Meetings have been planned for next season, to extend over four days or more in all. Similarly, the Transportation Meeting three years ago occupied two days, but three days are to be allotted to it next fall. In 1925 three days were enough for the Annual Meeting of the Society. Currently it occupies four days.

The Sections have been expanding their activities in a somewhat different way. The Detroit and the Cleveland Sections began by holding production meetings between the times of their regular monthly meetings. Last winter the Detroit Section started a new movement by organizing a Body Division and an Aeronautic Division. This innovation may extend to other Sections.

Another development that has increased the number of papers coming to THE JOURNAL is the tendency of the Sections to have presented at their monthly meetings a group of several papers on a given general subject. President Wall feels it would be better to have one paper of prime merit at a meeting, prepared discussion on different phases of the subject, followed by extemporaneous discussion, being presented.

One means that is already being tried for relieving to some extent the pressure on the available space in THE JOURNAL is the separate mailing in mimeograph form of some of the papers that are of special interest to production engineers and operation and maintenance engineers and executives. Considerable encouragement has attended the issuance of the first paper in this form, entitled Importance of Chassis Lubrication and Tightening, by D. R. McBryde. One large company has distributed this paper among its service organizations in this Country and in 18 foreign countries. Copies of the paper are available at the office of the Society to any other members who desire them.

Chase Wins Tennis Championship

THE final match of the Men's Single Tennis Tournament, which could not be played off at Quebec, was played at the West Side Tennis Club at Forest Hills, Long Island, on the afternoon of July 30, Herbert Chase winning the championship by defeating J. P. Nikonow 3—6, 7—5, 6—4. The score does not indicate the closeness of the match, Nikonow leading in the second and third sets until after a hard battle.

The Airplane in Canadian Exploration

By A. M. Narraway[1]

Semi-Annual Meeting Paper — *Illustrated with* Photographs

Canada has been settled only along a narrow fringe next to the United States; to the north is a vast undeveloped area of which accurate maps did not exist a few years ago.

The spectacular achievements of the aviators of other countries, typified by the racehorse, have been matched by the mapping exploits of Canadian aviators, typified by the workhorse.

Aviators cannot be expected to do the whole work of aerial surveying. The results are obtained by a division of labor, with experts in geology, forestry and other branches as well as aviation.

Descriptions are given of the method of taking the photographs, which differs from other photographic mapping-methods; of plotting the data on a map; and of preparing type maps showing the condition of the lumber resources of a region.

Water-power development is a new and very important field for photographic investigation. The sources of a stream can be investigated readily, and the most suitable dam sites can be determined with certainty. The study of geology and the location of roads and railroads are among the many other uses to which aerial surveys are adapted.

ONE of the occasions in a lifetime which is really appreciated is an opportunity to give some public recognition to those workers who are building permanently and efficiently so that others depending upon that building can also build a firm structure. I am, therefore, grateful for the opportunity to present this paper.

The title offers a very wide scope for any writer in a country such as Canada, where there remains so much undeveloped, unmapped and unexplored territory. The phase of the exploration by airplane to which I wish to refer is that which relates to the investigation and development of Canada's natural resources, more commonly referred to as aerial surveys and aerial investigations.

First, it must be understood that settlement in Canada has been along a comparatively narrow fringe more or less adjacent to the boundary between it and the United States. The area of this fringe does not exceed 20 per cent of the entire area of the country. This 20 per cent consists of the prairies of Western Canada and the farms and settlements hewn out of the bush by our ancestors, as long ago in many cases as Champlain's time. Four-fifths of this large country remains to be explored and mapped.

Second, it may be necessary to point out that this northern four-fifths of the country yet to be developed is a storehouse of nature. It probably would be correct to say that this area contains four-fifths of Canada's natural resources. Hence, it can be readily understood why a field exists in Canada that probably is unequalled in any other country, for the useful and economical application of aircraft.

A Map Is a Key

The first purpose to which the airplane has been put in this country, after its use as an agency of transport, is in connection with mapping from aerial photographs. Mapping naturally is the starting point of all investigations of any natural resource. No country would go very far in developing forestry or mining, for example, without a map, which is a catalog or directory of the main features of a country, upon which one can build.

But aerial mapping, or aerial surveys, go much further than mapping; for the aerial photograph is a true image, or bird's-eye view, of the country itself. No matter how inaccessible such country may be to the forester, the geologist, the capitalist, and to all who are interested in the development of its resources, the sound development of a resource is in a direct ratio to the knowledge and the availability of that resource. The objective, therefore, of aerial exploration or aerial surveys in Canada is the searching out and building up of a knowledge of our resources.

We all have followed the development of flying through its various stages since, scarcely a generation ago, man first succeeded in manipulating an airplane in the air for a few hundred feet. With an almost overnight development we have seen it evolve into an indispensable instrument of war, then almost immediately become an agency of wide diversity of peace-time application in mail and passenger carrying, mapping, dusting crops and timber, and fire patrolling; and later, especially during the last year, we seemed to be rushed into a series of long-distance flights, traversing the North Pole, spanning the Atlantic, reaching India, the Far East and the Hawaiian Islands; until, finally, a visit to the South Pole is now being planned.

Canada's Contribution to Aviation

In view of the widespread publicity that has attended these long-distance flights, nearly all of which have been conducted or attempted by fliers of other countries, Canada's contribution to the development of the use of aircraft has not been fully appreciated. It is true that

[1] Assistant director and chief aerial surveys engineer, Topographical Survey of Canada, Ottawa.

FIG. 1—A GROUND-SURVEY LINE

This Is a Part of the Manitoba-Ontario Boundary Line. Note the Concrete Monument, Transit Station Platform, and Picket with Crossbar in the Foreground and the Cut Extending Through the Forest at the Horizon, beyond Bradburn Lake. This Cut Shows a Typical Stand of Timber

she has not sent planes to the North Pole or across the Atlantic. Money has not been available, fortunately, we think, for undertakings of this kind. Yet Canada has attained a leadership in at least one branch of aviation—that of aerial surveys and air investigations. Why do we not hear more of her achievements? I think it can be explained best in this way: Canada has been developing the workhorse, not the racehorse; the effective, not the spectacular; a workhorse which, as I hope to demonstrate, is making history, and it shortly will be recognized universally as one of the most potent factors contributing to the development of this country.

In place of the record flights across the Atlantic, Canada points to the record of photographing, within five years, of more than 200,000 square miles of hitherto inaccessible country that is richly endowed with natural resources. Such an accomplishment is equivalent to eight flights completely around the world, with a photograph of every foot of the way. For that brilliant North Pole flight, Canada points to the aerial protection from fire of approximately 200,000,000 acres of forested lands each year. For the Hawaiian Islands flight, Canada points to the type-mapping of timber to an extent of over 30,000 square miles of almost completely unmapped country in one season. For the Flight to India and the Far East, Canada points to the words of a geologist who says: "Such work has entirely revolutionized the geological survey"; or to the words of an eminent consulting mining-engineer of Los Angeles who used the aerial map on a recent visit to The Pas mineral district in northern Manitoba and said: "I know of no initial step in the examination of the geological resources of the country better than the mapping that is being done by aerial surveys," and: "In all my experience I never have seen a map equal to the map of that area."

The comparison of our workhorse to other countries' racehorses is not designed to undervalue the brilliant achievements of other countries. One follows the development and activities of the racehorse with the keenest interest—the preparation for the race, the excitement, the anxiety, and finally the grand finish; a new record attained, a new ribbon added. But Canadians do not forget that horse of their own—out early in the morning, working all day, at it again the next day, and so on during the season; working over courses uncharted, over regions untrod, yet over areas of untold wealth. There is no excitement, no glamour, no broadcasting of the day's work; but, notwithstanding its seeming dullness, it also has won a ribbon and has hung up a record which places Canada in the foreground of aerial development. A record of achievement? Yes; but, to Canadians, the other interpretation of that world record is the thing of importance. Canada's workhorse has brought to the hand of the geologist, the engineer and the citizen at large a real record in the photograph of the country itself, in black and white, for all to read.

And so, while Canadians have seen and appreciated the brilliant achievements of the fliers of other countries, they have looked, from force of circumstance if you will, to their own workhorse; for its achievements have moved at least one generation ahead the development of Canada's resources, and the airplane can be seen actually playing a vital part in developing a huge country and enabling it to take its place as one of the nations of the world.

So vital a part is the airplane playing in the development of their country that Canadians are looking to the automotive engineers to provide airplanes capable of giving the performance that will enable the fliers to carry out their onerous duties with efficiency and all reasonable safety.

No discussion of any phase or application of air development would be complete without some special reference to the cooperation of the airman, or, in Canada, to the officers of the Royal Canadian Air Force. I should like to make very clear the airman's position in relation to the development of aerial surveys and investigations in Canada, both in fairness to him and to explain why Canada has made such marked progress with this work.

At the conclusion of the Great War we all heard statements that the airplane and aerial photographs would so revolutionize investigations that the surveyor or the ground man would be eliminated. The absurdity of this statement now seems so obvious that it may be wondered why it has been mentioned. Unfortunately, many people seem to be carrying on still under such a system, expecting remarkable results from aerial work. They expect the pilot to map, to classify timber, to locate

railroads and to do other work of this nature, and they wonder why the plan does not seem to be successful. One hears the statement that the Air Force has mapped this and has investigated that. Nothing could be farther from the truth or more unfair to the pilot than such a reference, nor could there be any more absurd application of aircraft. Fortunately, in Canada this situation was detected in time and corrective measures were taken.

Pilots and Specialists Work Together

Canada looks to the Air Force to equip a suitable airplane; to send it into the air every day that is suitable for photographing, of which there are only about 25 or 30 in a season; to get it to a definite altitude, and keep it there for the full period of photographic light. The pilot must fly a straight line over unmapped country. He must keep the plane level, at an even keel. and at a constant speed. Canada expects a great deal from its pilots, as these requirements are exacting. But Canada does not expect the impossible; she does not ask the pilot to be a geologist, a surveyor, a water-power engineer and a forester combined. She does not ask him to classify soils or to locate a railroad, nor does she condemn aerial surveys because he cannot do all these things.

Canada says to the Air Force: "You meet the flying requirements, our experts will use your planes as a quick agency of transport over inaccessible areas, and to get a bird's-eye view of the country, and will use the aerial photograph." And so Canada has developed an efficient airman for air duties and has trained its investigator—be he geologist, forester, surveyor, or other expert—to use the airplane much as he uses any other instrument. Hence her leadership in this field of aerial investigation.

One looks at a paper plant in the outskirts of a city and notes the hum of the machines and the air of activity in such a plant, giving employment to thousands of people and shelter and food to their families and generally contributing to the welfare of that city. Unfortunately, it does not occur to him readily that this scene is possible only because of the certain knowledge that, away up beyond in the areas shown blank on the

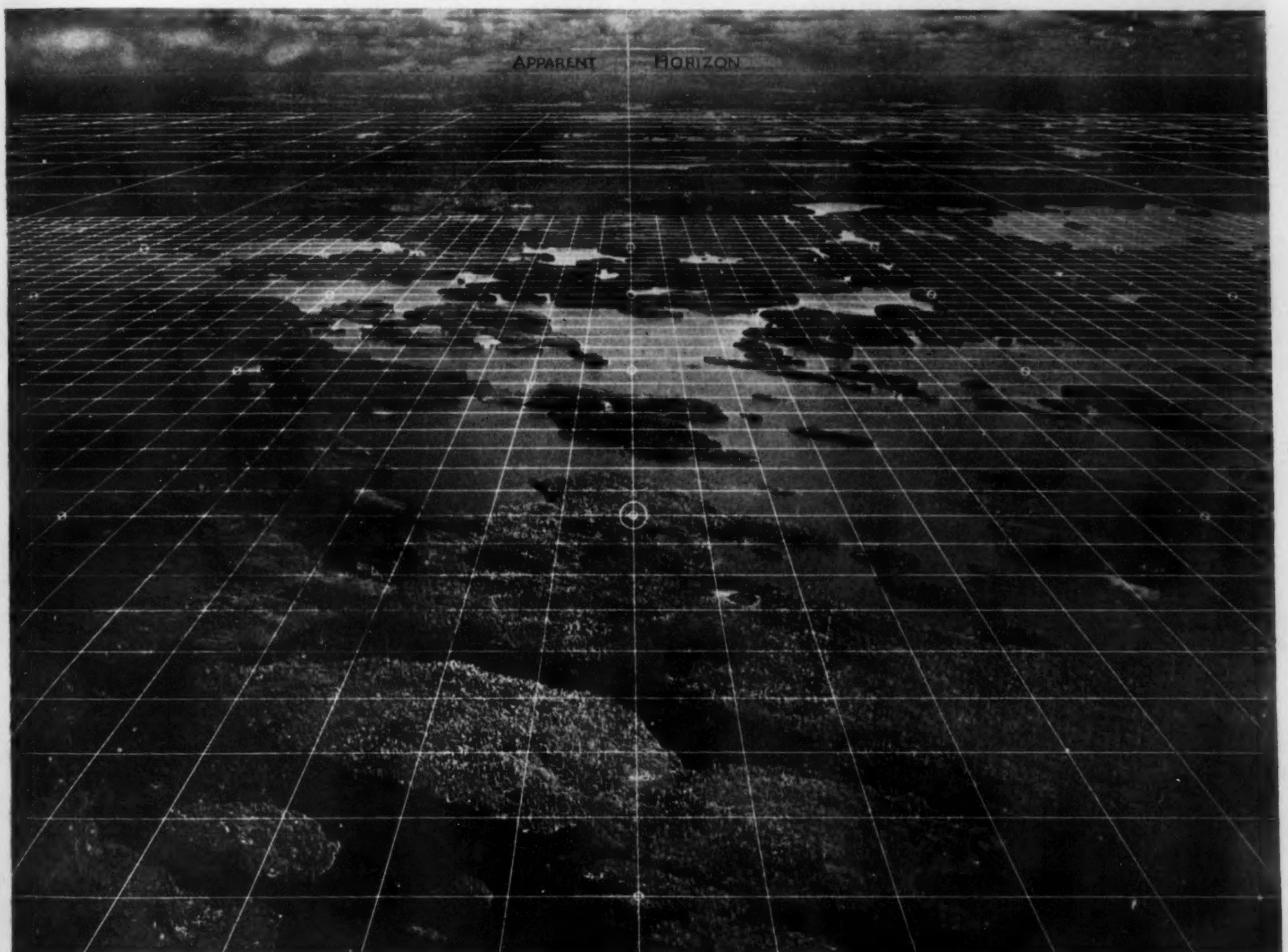

Fig. 2—Plotting from Oblique Aerial Photographs

Upon the Oblique Aerial Photograph a Grid Is Superimposed, Drawn in Perspective To Correspond with the Perspective of the Photograph. The Information Is Then Transferred Square by Square to the Map Plot, the Latter Having Been Ruled into Similar Natural Squares. This View Is Taken from an Elevation of 4000 Ft., with a Focal Length of 8.264 In. The Distance from Ground Plumb-Point to Grid Center Is 153.92 Chains. The Apparent Horizon Is Indicated on the Engraving

FIG. 3—AERIAL PHOTOGRAPH OF FORESTED AREA
From a Series of Photographs Such as This an Aerial Map Can Be Made That Shows the Nature, Location, Extent and Accessibility of the Forests

map, there exists raw material sufficiently available and abundant to maintain such a plant. I say "unfortunately" because, when investigators and mappers are outfitting to explore these blank spaces, they have difficulty in convincing the public that the comparatively far-away places are of vital importance to them, and are not so far away after all.

How the Knowledge Is Used

As the forester now increases his knowledge of the timber in these spaces, known as the hinterland, he is able to recommend the building of other plants in the same district; just how many more depends upon the knowledge he may be able to obtain of further timber-resources in the blank spaces adjacent to the district. This is true for all other districts lying on the borders of the hinterland of Canada. These blank spaces exist on the map solely because bush areas are difficult of access by ordinary ground methods often involving cuts through the forest, like that shown in Fig. 1, and are very expensive to investigate. Hence, the first field for the airplane, which knows not the difficulties of the bush for the ground man. It changes an investigation from 1 or 2 m.p.h. to a speed of 70 or 100 m.p.h., at the same time giving the investigator a comprehensive bird's-eye view of the whole area under examination, recorded accurately and completely by the camera in the plane. A similar service is rendered to the water-power engineer, the geologist, the surveyor, and other investigators.

Until about 40 years ago, mapping in Canada was confined almost solely to charting main waterways or main routes to give access in a big way. Since then, detailed mapping—or mapping which can be considered to be serviceable to timber protection and development, geology and water-power—has been carried out on the prairies of Western Canada and in other more settled parts of the country. In all, approximately 240,000 square miles have been so mapped. Very little has been done outside settled areas; in fact, a map showing the progress of the work in Canada would be very largely coincident with the settled portions of the country.

Looking at a map made from aerial photographs, it will be seen that, during the five years in which this work has been carried on, more than 200,000 square miles have been covered. It will be noticed, also, that almost all of this large area lies outside settled regions, in those areas hitherto regarded as inaccessible. The word "inaccessible" has been removed, respecting these areas, and we have in its place a map, complete and reliable in detail as to topography, with a photograph

underlying every part of it, revealing the character of the land for a study of its resources.

The first experiments in aerial surveys in mapping Canada's hinterland were made in northern Manitoba, in what is known as The Pas mineral area. So striking were the differences between the aerial map and the former map that it was apparent at once that the experiments were worth continuing. It is of interest to note that, in this area which was supposed to be fairly well known, more than 800 lakes were added to the map, which also showed rock exposures in the heart of the woods to direct the footsteps of the prospector and the geologist. As a matter of fact, the aerial map and the aerial photograph so portrayed the country that the geologist was able at once to delete the waste areas from his investigation and proceed directly to the study of the geology.

Making Photographs for Mapping

The method of making a map in a hinterland district is strictly Canadian and peculiarly adapted to this country. A camera, capable of taking 7 x 9-in. pictures automatically, is mounted over the nose of the airplane, the engine being mounted out of the way in the wings. The camera operator, standing in the front cockpit and having free vision ahead, takes a perspective photograph straight ahead; and then, rotating the camera to the right and to the left, takes photographs on either side of the line of flight. Thus he obtains pictures in sets of three showing the country for a full 180 degrees. These sets are repeated at intervals of 2½ to 3 miles. This close interval assures an ample overlap between consecutive sets of photographs, which makes it possible to carry the scale of one set into the next succeeding set, and so on across a long distance between measured traverse lines.

The plane is flown at an altitude of 4000 to 5000 feet above the terrain, in parallel flights about five miles apart, across the entire area to be covered. Utilizing the abundant overlap between consecutive photographs, a straight line is projected between common points identified on the photograph from the first picture through to the final photograph on a flight line. This straight line is easily picked up at its ends, as it

Fig. 4—Aerial Photograph of Water-Power Site

This Photograph Is of the White Dog Falls on the Winnepeg River in Ontario, near the Manitoba Boundary. Viewing Adjacent Photographs under a Spectroscope Brings Out the Contour of the Land in Relief

usually crosses main or accessible waterways, and is "tied in," to use a surveying expression, by a ground surveyor who traverses these waterways. The fixation of these terminal points fixes in turn every photograph along the entire course of the flight, which may be 100 miles long. In early days, now nearly forgotten, our reliable washwoman attached one end of the clothesline to the shed and the other end to a neighbor's fence, and then she knew that every article of clothing was fixed in position. This is the result obtained when the ground surveyor fixes each end of the line of flight.

How the Map Is Plotted

The next step is to plot or transfer to a map the intricate mass of detail visible in the various photographs. This result is accomplished by superimposing on the photograph a system of small squares ruled on glass, corresponding in perspective to that of the photograph, as shown in Fig. 2, and then transferring the information square by square to a map that has been ruled previously into similar natural squares. In this simple way the map of the whole area is built up, square by square, photograph by photograph. This map shows all essential information—relating to lakes, waterways, roads and other important culture—completely and truthfully, regardless of the fact that the ground man has entered the territory only along main waterways which may be separated by 50 or more miles.

A comparison of the aerial map with the best available map preceding it will reveal the wealth of detail that has been added. On many map-sheets we have found that more than 2000 lakes have been added. The value of such a map to the prospector, geologist, forester, or other investigator is obvious. With a study of the photograph, it enables him to go directly to his objective, knowing that he has a correct base-map upon which to record any notes or information he acquires. Thus we have the first real contribution of the aerial photograph to the investigation and the development of natural resources.

It is well known that Canada's forest resources are enormous, and every effort is being made to search them out and to study carefully the best means of penetration and development. An aerial photograph is invaluable to the forester, and from it he is able to obtain an increased knowledge of available raw-material with a dispatch, a certainty and a finality that cannot be had otherwise. A photograph like Fig. 3 gives evidence of the quantity and quality of the timber. Fortified by an aerial map showing the location, extent, and accessibility of forests, the forester is enabled to assume the responsibility of recommending the establishment of pulp and paper plants and other consequent expenditure.

From the aerial photograph, what is known as a type map is prepared. The useful or merchantable timber is shown by one color. Another color designates the young stands, another the burns, and other colors single out the swamps, water areas, and other information of importance. Such a type map at once enables the forester to direct the fire-protection planes to the useful areas and enables an efficient fire-protection system to become effective. From the type map the forester obtains all the essential information on how to develop the merchantable timber and get it out to the mill.

So successful has this application been that last year alone we were called upon to produce type maps for more than 35,000 square miles of forested land.

Perhaps the greatest advance in the aerial-surveys field during the last year is the application of the photograph to the investigation of water-power resources. The water-power engineer must have a definite knowledge of the water possibilities of any given district before he can assume the responsibility of recommending financial outlays. To gain knowledge such as is shown in Fig. 4, he must see beyond the settlements near the mouths of our rivers, away back to the headwaters of the streams.

These headwaters are about as difficult of access for surveying as possible. They are among swamps and muskegs and thick bush. However, these handicaps to the ground investigator are nothing to the aerial photographer, and the establishment of the drainage area of a stream is not difficult for him. The river, with all its branches, even to the little contributing streams, stands out prominently, especially when viewed under the aerial stereoscope, and it is easily mapped.

Having determined the drainage area of a stream, the next problem is to locate suitable areas where the freshet waters may be impounded in reservoirs to preserve a continuous supply of water and a constant head. Further, this impounding of water necessitates the location of suitable and economical dam sites. The erection of dams causes a flooding of land, including good timbered areas and, in some cases, valuable farm lands; and so, before constructional work can proceed, the actual flood-line must be determined.

If aerial surveys could be considered as being peculiarly adapted to some one purpose, the location of storage areas, dam sites and flood lines would surely be regarded as its particular function.

The Problem of Indexing

In endeavoring to meet the heavy demands that have been made for aerial surveys, we have taken approximately 172,000 photographs during the five years of existence of this new science. Last year about 50,000 pictures were added. The indexing of those photographs is a heavy task, if chaos is to be avoided.

Curiously enough, a suitable indexing system was worked out, in a sense, by Aerial Surveys itself. Up to the introduction of this new science, Canada did not have a national map. This was because such a large proportion of the country was impossible to map economically by ordinary ground-methods, so that only maps of areas of special importance could be attempted. The initiation of aerial surveys made possible the introduction of Canada's National Map, based upon latitude and longitude, giving uniformity and coordination throughout the length and breadth of this great country; a structure of permanency, each map-sheet fitting its neighbor snugly, as one story of a structure fits to the next. Here was our index for the photographs, which changed the prospect of chaos into rigid order.

If I may assume the rôle of a prophet, I shall predict that the mists of ignorance which now cloud so much of Canada's hinterland will be dispelled in the near future by aerial-survey methods. In the place of stories based on tradition, accurate knowledge of the resources will be obtained and sound principles of conservation and development can be adopted. The aerial maps will show the country as it is, and the aerial photographic library will be a storehouse of information available to all who are interested in any locality or in any resource.

The Influence of Fuel Characteristics on Engine Acceleration[1]

By DONALD B. BROOKS[2]

SEMI-ANNUAL MEETING PAPER | *Illustrated with* PHOTOGRAPHS, DRAWINGS AND CHARTS

SELECTION of a method and development of apparatus enabling precise and detailed measurement of engine acceleration is discussed in the first portion of this paper, the latter portion of which is concerned with the experimental results thereby obtained.

Previous work on the influence of engine conditions on acceleration is generally substantiated. A method is described for approximately deriving the effective air-fuel ratio delivered to the cylinders during acceleration, practical applications are suggested, and limitations are discussed.

The effect of fuel volatility on engine acceleration was studied, using six fuels: Aviation gasoline; commercial gasoline; a blend composed of equal parts of the two; and three especially prepared fuels, all of which have equal 20 and 90-per cent points but differ widely at the 50-per cent point. It is shown that the relative values of these fuels for acceleration depend upon the amount of vaporization in the manifold.

ABOUT May 1, 1920, the Committee of this Society on the Utilization of Present Fuels in Present Engines requested the Bureau of Standards to undertake research in connection with a "more miles per gallon" movement initiated by the Committee. The program as outlined included measurements of engine performance under conditions of both steady running and acceleration.

In making tests incident to this work, a method for measuring acceleration was devised, as reported to the Society in papers[3] by W. S. James, Dr. H. C. Dickinson and S. W. Sparrow, which was used with but very minor modifications until the first of this year. This consisted essentially of operating the engine at light load and low speed, suddenly opening the throttle fully, and noting the successive readings of a chronometric tachometer until a certain predetermined higher speed was reached. Readings were taken also with a chronograph, which recorded time and engine revolutions. This latter apparatus was not used in subsequent work. Results were expressed as speed-time curves.

With the organization of the Cooperative Fuel Research, in the summer of 1922, came further work on acceleration, with especial reference to the effect of fuel volatility. This work was first done on the road, using two makes of car, and was reported to the Society in papers by R. E. Carlson[4] and Roger Birdsell[5]. A graphic record of car-speed changes during runs was obtained by connecting a pen movement to a Van Sicklen chronometric tachometer. The conclusion reached was that the effect of the fuels on acceleration was not measurable by road test. Laboratory tests, however, did show decided differences in acceleration results between fuels which differed in volatility but had nearly the same initial point. As an appendix to Mr. Birdsell's paper, a mathematical discussion[6] was given by Mr. James of the design of the inertia disc used in laboratory tests to simulate the inertia of the car.

On Dec. 4, 1925, the Steering Committee of the Cooperative Fuel Research recommended that

> The study of engine starting, which has thus far dealt with the obtaining of the initial start, ultimately should cover the behavior of the engine during the warming up period, particularly as regards acceleration.

As a preliminary to this, a general study of engine acceleration was made, as reported by J. O. Eisinger[7], using a chronometric tachometer. This work showed decided differences in initial lag under different conditions and, to a less degree, differences in acceleration can be inferred from the speed-time curves shown. In the course of this work, however, it was desired to determine the acceleration obtained with each of three fuels whose 20-per cent and 90-per cent points were identical but whose 50 per cent points were widely different. This work was reported[8] by R. Best and J. O. Eisinger. The results obtained were not sufficiently accurate to enable conclusions to be drawn. Since the chronometric-tachometer method of obtaining speed-time curves had been used and improved for over 7 years, it was believed that better results might be obtained by employing new methods than by attempting further to improve the existing installation. A study of possible methods was therefore made.

METHODS FOR MEASURING ENGINE ACCELERATION

Acceleration is the rate of change of speed, or the rate of change of the rate of change of position. Mathematically it is the first derivative of velocity with respect to time, or the second derivative of displacement with respect to time. Obviously, therefore, there are three possible ways of obtaining acceleration:

(1) By direct measurement
(2) By measuring speed and time
(3) By measuring displacement and time

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[1] Published by permission of the Director of the Bureau of Standards, City of Washington.

[2] Jun. S.A.E.—Research associate, automotive laboratory, Bureau of Standards, City of Washington.

[3] See THE JOURNAL, August, 1920 p. 131; and January, 1921, p. 3.

[4] See THE JOURNAL, February, 1923, p. 139.

[5] See THE JOURNAL, March, 1924, p. 267.

[6] See THE JOURNAL, March, 1924, p. 271.

[7] See THE JOURNAL, August, 1927, p. 184.

[8] See *Bulletin of the American Petroleum Institute*, Jan. 31, 1928, p. 74.

The first of these methods utilizes the fact that, when a potential varying directly with speed causes energy to flow into capacity, the rate of flow is proportional to the acceleration. This principle applies equally to mechanical, electromagnetic, or electrostatic means. In the mechanical application, kinetic energy of rotation may be stored in the inertial capacity of a metal disc connected to the source of power by a flexible shaft, the torsional twist in the latter being proportional to the rate of flow of energy into the disc. The electromagnetic application may be made by measuring the induced voltage in the secondary winding of a transformer when the primary winding is connected to a direct-current magneto-generator driven by the engine. Similarly, the electrostatic application consists in measuring the current flowing into a condenser from a direct-current magneto-generator connected to the engine. The limitations of these electrical methods are stated in a book[9] by George Keinath. The mechanical application has been tried in several forms by the Bureau, but it was abandoned because of friction difficulties.

An illustration of the second general method is an electrical tachometer, which is essentially a voltmeter connected to a magneto generator that is driven by the engine. This instrument gives instantaneous speed, from which a speed-time curve can be obtained. It is possible to obtain the acceleration by differentiating this curve.

A chronometric tachometer is essentially a displacement-time indicator. It counts engine revolutions during a certain period, then indicates the sum on a scale calibrated in revolutions per minute. From the speed-time curve thus obtained, a single differentiation gives acceleration. It is important to note, however, that an approximate numerical differentiation of the measured displacement-time has already been made by the tachometer. Thus two differentiations have to be made to obtain acceleration from the data, which greatly magnifies the errors inherent in the instrument. The errors of numerical differentiation are treated in Appendix 1.

An adaptation of the displacement-time method, which has been adopted for use in this investigation, consists in driving a paper tape at a speed proportional to the engine speed and discharging a spark through the tape at equal time-intervals. A displacement-time record is thus obtained, the second derivative of which gives the acceleration.

One reason for selecting this particular method is that the absolute measurements involved can be made with sufficient precision to permit of double differentiation and still yield results of the desired accuracy. Further increase in precision can be obtained by increasing the distance traversed per unit of time.

Description of Apparatus

The test equipment, which has been described by Mr. Eisinger in his paper to which reference has been made, consisted of a 1926 passenger-car engine coupled to a Sprague electric dynamometer, the electrical and inertial loads applied being such as to simulate level-road direct-gear driving-conditions. The setup is shown in Fig. 1. The manifold was jacketed and all temperatures were measured by thermocouples. The carbureter as used had only main and idle jets, the economizer and the accelerating well being blocked off. During constant-speed runs for determining air-fuel ratio, fuel was measured volumetrically and air by means of orifices in thin plates mounted on a box attached to the carbureter. Appendix 2 discusses the accuracy of this method.

A device was used which permitted the throttle to be opened only at a definite point in the cycle of the engine, assuring starting the acceleration run under similar conditions each time. Another device records the instant of throttle opening on the paper tape used in the accelerometer.

The spark accelerometer, as originally constructed, is shown in Fig. 2. Sprocket A, driven by the engine, draws perforated paper tape between electrodes B, across which a spark is discharged. This spark is timed by a half-second Mercer chronometer, not shown, which operates relay C, breaking the primary circuit of igni-

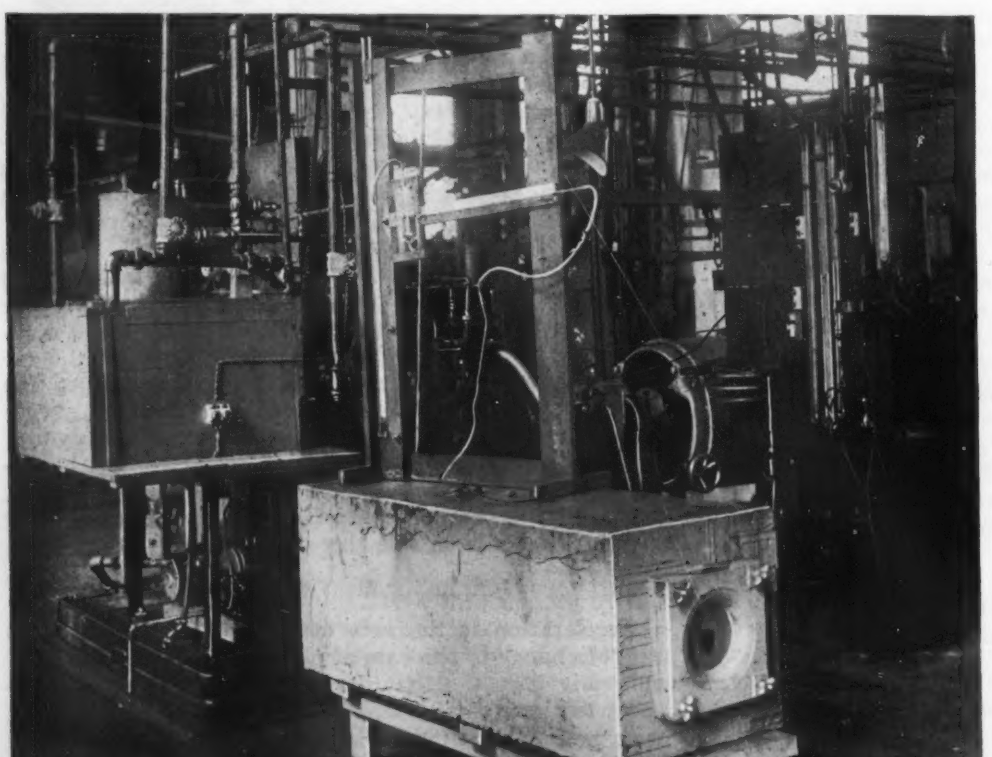


Fig. 1—Laboratory Set-Up for Acceleration Tests

[9] See Die Technik der Elektrischen Messgeräte, second edition, pp. 426-429; R. Oldenbourg, Munich.

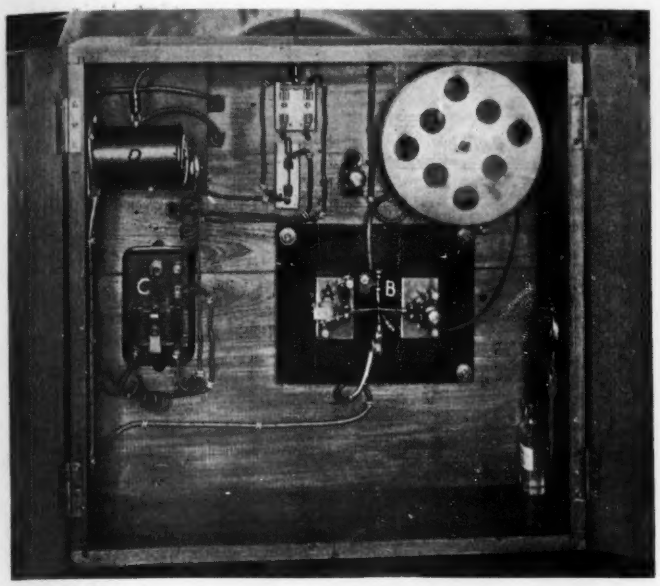


FIG. 2—ORIGINAL ELECTRICAL PANEL FOR TESTS
This Panel Was Superseded by the One Shown in Fig. 5. *A*, Sprocket for Driving Paper Tape; *B*, Spark Gap; *C*, Relay; *D*, Spark Coil

tion coil *D*. A diagram of the electrical connections is shown in Fig. 3.

Fig. 4 shows the first gear-train and clutch used to drive the sprocket *A* in Fig. 2. Four fiber-gears were used in the train, and relatively large errors were found to be introduced by the eccentricity of these gears.

While temporarily using this apparatus, a study was made of the errors. These can be classified as:

(1) Error of timing spark
(2) Spark wandering, or not taking the direct course between electrodes
(3) Error due to gear eccentricity

By means of a quarter-second pendulum, the first error was evaluated as $\pm$ 0.0007 sec. or $\pm$ 0.14 per cent. By passing sparks with the engine stationary and set in successive fractions of a revolution, the second and third errors were evaluated; that of spark wandering being equivalent to $\pm$1.0 r.p.m. and that of gear eccentricity being roughly the same.

The resultant probable error is the square root of the sum of the squares of these errors, and is given below, together with values directly obtained by constant-speed operation.

Revolutions Per Minute	Calculated Resultant Probable Error, R.P.M.	Observed Error, R.P.M.
300	$\pm$1.4	$\pm$1.3
600	$\pm$1.6	$\pm$1.8
1000	$\pm$2.0	$\pm$2.0

Attempts were then made to reduce each error. High-grade relays were obtained, and the customary plain-bearings were replaced with steel cones bearing on brass. The relay, shown mounted on the box in Fig. 2, was mounted in a spring suspension, damped by a plunger immersed in oil, as shown in Fig. 5. This was found necessary to damp out engine vibration, which otherwise caused chattering of the relay clapper, with consequent multiple sparks. By this means the time error was reduced to $\pm$0.00042 sec. which seemed to be the limit for the chronometer.

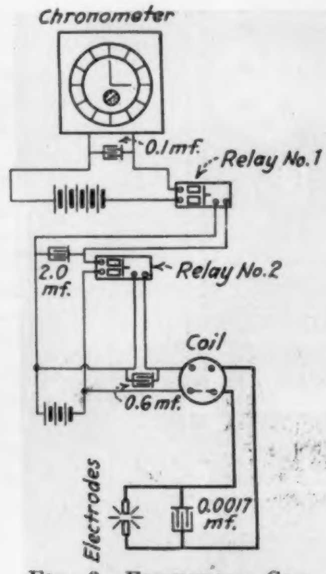


FIG. 3—ELECTRICAL CONNECTIONS FOR CHRONOMETER-TYPE SPARK-ACCELEROMETER

Eastman Ciné Kodak 16-mm. film leader-strip was then substituted for paper tape, in the hope that spark wandering would be reduced with the more homogeneous film. However, 16,000 volts failed to puncture the 0.007-in.-thick film, jumping around it unless the electrodes were immersed in oil. This line of attack has not been pursued further.

A new gear-set was made, shown in Fig. 6, permitting either direct-drive or 4 to 1 reduction. By this means, gear eccentricity was practically eliminated when using the train. When using direct drive, the error due to spark wandering is found to be reduced to one-quarter of the value given for driving through the gears.

The improvement in accuracy thus obtained was satisfactory, but certain phenomena were obscured by the half-second interval between measurements. To obtain shorter time-intervals, a tuning fork was substituted for the chronometer, the revised accelerometer being shown in Fig. 5 and the electrical connections in Fig. 7. As used in most of the subsequent work, the fork was loaded to give a frequency of 13.6 cycles per sec.; in certain runs the load was removed, giving a frequency

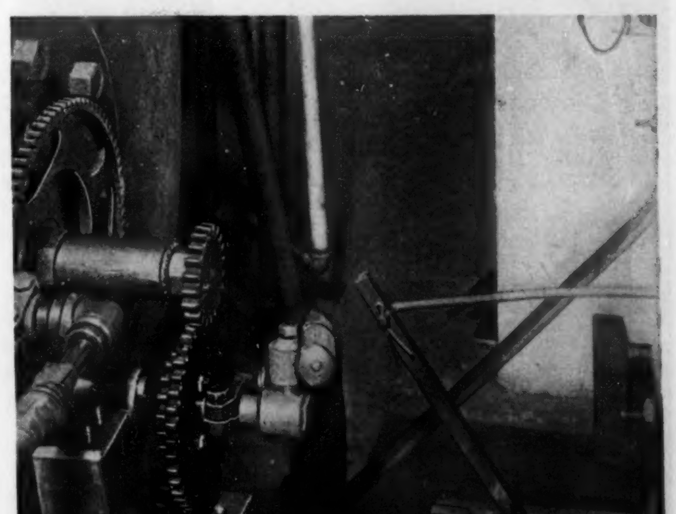


FIG. 4—ORIGINAL GEAR-TRAIN
This Train of Fiber Gears Was Used To Drive Sprocket *A* in Fig. 2

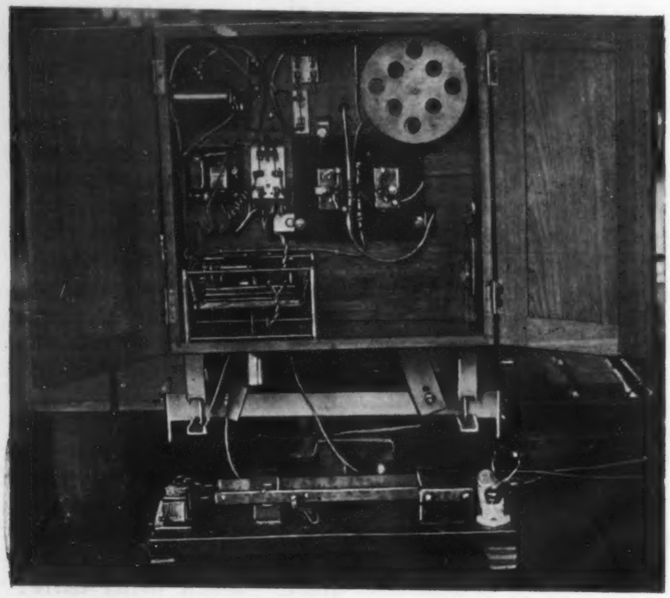


FIG. 5—IMPROVED PANEL FOR TESTS
This Panel Embodied Improved Electrical Units and a Spring-Suspended Vibrator with Dash-pot, as Shown at the Lower Left Corner of the Box

of 25.9 cycles per sec. At this latter frequency, the measurements are about twice as numerous as the cylinder explosions at the initial engine speed of 300 r.p.m. The improvement in accuracy, however, was not sufficient to justify the increased work involved in measuring and computing results. Apparently the time

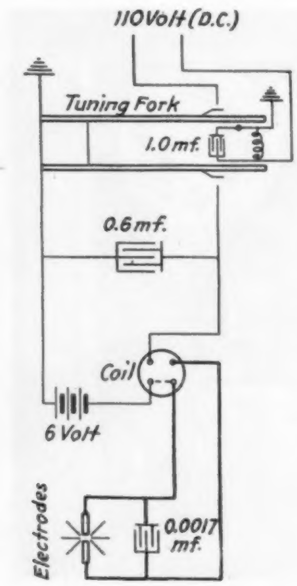


FIG. 7—ELECTRICAL CONNECTIONS FOR TUNING-FORK TYPE SPARK ACCELEROMETER

error of the signals is negligible in comparison with the spark wandering; as the error, computed as displacement, was ±0.015 cm. for both the 13.6 and the 25.9 frequencies. This is equivalent to a time error of ±0.0005 sec.

Displacement measurements have been made on a micrometer comparator, reading accurately to 0.001 cm. It is intended, however, to construct special apparatus as sketched in Fig. 8. The number of paper-sprocket revolutions is the quantity which must be known, it is therefore more satisfactory to measure this directly than to measure linear distances and reduce them to revolutions. This has been done

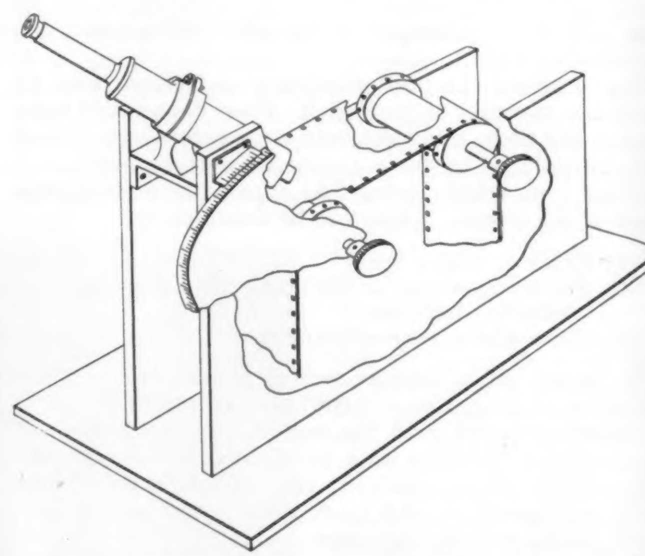


FIG. 8—SKETCH OF PROPOSED MEASURING-APPARATUS

by measuring the linear distance between eight perforations, which distance corresponds to one revolution of the eight-tooth sprocket. The proposed instrument, moreover, can readily be made to read engine speed directly in revolutions per minute if a known constant frequency of time signals is used. Thus, with a 1/6-sec. tuning-fork and direct drive on the sprocket *A*, Fig. 2, the scale on the disc of the measuring instrument must have 360 graduations for reading engine revolutions directly. This combination is recommended as giving sufficiently high frequency for most work; furthermore, a readily obtainable protractor graduated in degrees can be used on the measuring instrument. Probably it is not profitable to use frequencies much greater than 6 per sec. in ordinary work on acceleration, as the influence of each cylinder becomes quite noticeable at about 12 per sec. From this work, however, nothing can be found which would indicate that it is impossible, by go-

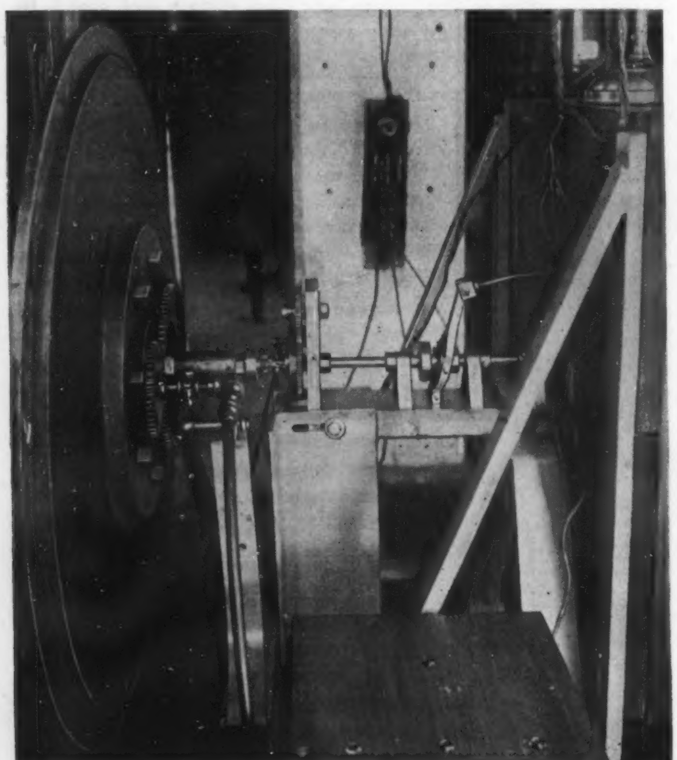


FIG. 6—IMPROVED GEAR-TRAIN FOR PAPER-SPROCKET
This Gear Train Was Used with the Panel Shown in Fig. 5, Replacing the Train Shown in Fig. 4. Improved Gears and Mountings Eliminated Inaccuracies from Eccentricity, and a Through Drive Was Provided

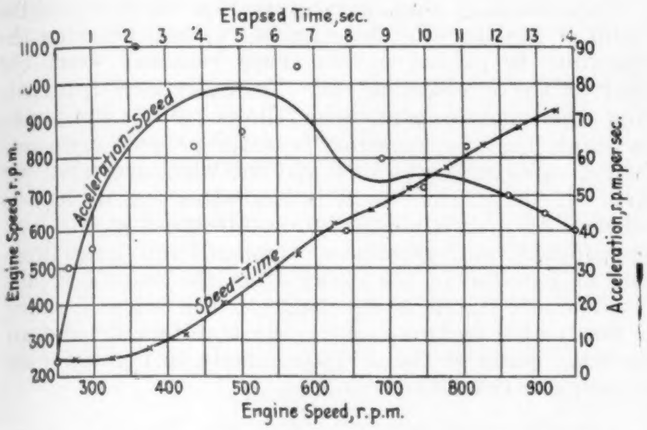


Fig. 9—Magnification of Scale by Changing Speed-Time Coordinates to Acceleration-Speed

ing to much higher tape-speeds and frequencies, to obtain in effect a brake indicator-card; that is, to register the rise and fall of pressure in each cylinder. To do this at 300 r.p.m., a tape speed of 15 to 25 ft. per sec. and a fork having a frequency of about 300 per sec. would be necessary. Obviously such tests would be very laborious, an hour's work being required for each second of operation.

Test Procedure and Results

In making a series of acceleration runs, the following test-procedure was used. The engine first was warmed up and the desired temperatures maintained. After roughly 20 min., an acceleration was made, starting a stop-watch at the moment the throttle was opened. Exactly 3 min. later another acceleration was made, and this process was repeated at like intervals thereafter. No readings were taken of these accelerations. After about ½ hr., readings were taken on the chronometric tachometer for each acceleration. When these readings were found to repeat, within the limit of error of the tachometer, the desired runs were made with the spark accelerometer in operation. Whenever any test condition was changed, preliminary readings were taken on the chronometric tachometer until successive runs were consistent. The importance of maintaining a definite time-interval between runs was demonstrated in a series of runs to determine this point. Acceleration decreased rapidly as the interval was increased up to 2 min., was nearly constant between 2 and 4 min. and became erratic beyond 4 min.

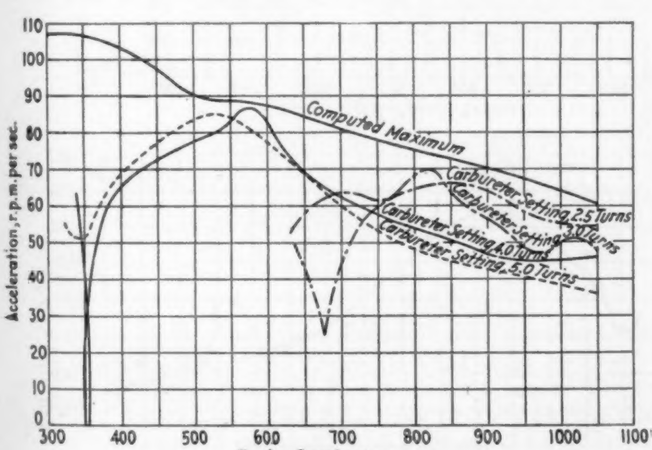


Fig. 10—Acceleration with Various Mixture-Proportions

These Tests Were Run with Commercial Gasoline, with Manifold and Jacket Water at 30 deg. cent. (86 deg. fahr.)

Conditions during the idling period between runs were maintained constant, and all readings were taken at definite times relative to the start of the acceleration run. This was deemed necessary in view of the fact that the operation is discontinuous and some temperatures are consequently varying throughout the cycle.

By way of transition from the speed-time curves used heretofore to the acceleration-speed curves used in this report, Fig. 9 has been plotted from the data of a run used in a previous report, selected as typical of the results obtained with the chronometric tachometer. The speed-time curve is seen to be quite smooth, points falling on or nearly on the curve. The acceleration-speed curve, with wide scattering of points, gives an idea of the magnification of the errors. Obviously, greater accuracy than that given by the chronometric tachometer is necessary if sound conclusions are to be drawn respecting acceleration. For this reason, some work previously reported has been checked with the spark accelerometer.

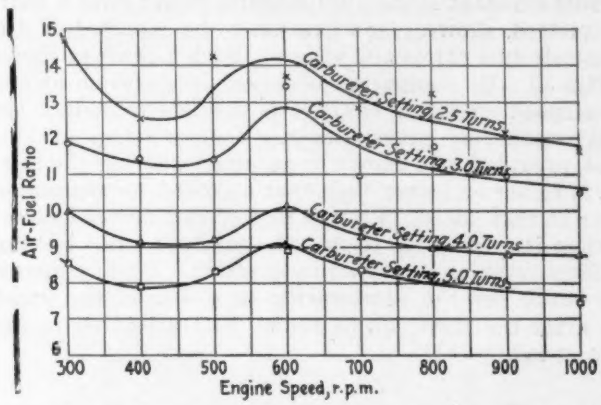


Fig. 11—Carbureter Characteristics at the Settings Used in the Tests

The results will be reported practically in their chronologic sequence; hence, since frequent minor alterations were made in the apparatus, usually improving the precision, the last results reported are considered more precise than the first. Modifications made in the carbureter having resulted in altered characteristics, early runs are not directly comparable with later runs in this respect.

Richness of Mixture

The effect of air-fuel ratio on acceleration was first studied. Results taken with manifold and jacket water at 30 deg. cent. (86 deg. fahr.) are shown in Fig. 10, while Fig. 11 shows the carbureter characteristics when this series of runs was made. Fig. 12 shows individual runs. At carbureter settings of 2.5 and 3.0 turns, the engine would not accelerate from 300 r.p.m.; hence the higher starting speed for these runs. The computed-maximum curve shown on Fig. 10 is derived from constant-speed air-fuel-ratio power-runs, and shows the acceleration that would be obtained if maximum-power mixture could be supplied throughout the acceleration. It is not to be expected that this computed maximum-acceleration can actually be realized, since it is based

on constant-speed tests, in which internal engine-conditions such as temperature and oil viscosity are quite different from those obtaining when accelerating after a period of idling.

From Fig. 10 it is seen that, at the start of the run, even with a rich mixture, acceleration is considerably below the computed maximum. This apparently is due to leanness caused by deposition of fuel on the manifold wall. Enriching the mixture diminished this initial lag, and a proper amount of accelerating charge might be expected to eliminate it.

Following the initial lag comes a rapid rise to approximately the computed maximum acceleration and, in the case of the richer runs, a subsequent decline due to overrichness. At the highest speeds attained in these tests, a tendency is shown again to approach the computed maximum-acceleration. Since the logical explanation appears to throw light on manifold behavior during acceleration, it will be given at some length.

From constant-speed air-fuel-ratio power-runs a chart was plotted, showing acceleration to be expected at different air-fuel ratios and speeds. Such a chart is shown in Fig. 13. By comparing observed acceleration at any given speed with this chart it is possible to deduce the effective air-fuel ratio *entering the cylinders* at this speed, provided it is known or assumed whether the mixture is richer or leaner than that required for maximum power at that speed. From a plot of carbureter characteristics it is possible to find the mixture ratio leaving the carbureter at the speed in question. From a speed-time curve for the acceleration in question, the exact time after the start can be found, corresponding to the given speed.

Correlation of these data gives Fig. 14, in which the ratio of fuel leaving the manifold to fuel entering the manifold is plotted against time reckoned from the start of the acceleration run. The story read from this and other similar charts is as follows. While the engine is idling, the inlet manifold is under reduced pressure; hence, vaporization is good and the walls are relatively dry. If the engine speed is low when the throttle is opened, as in this case, the low air-speed in the inlet manifold allows formation of comparatively large droplets of gasoline in the spray from the main jet; and considerable liquid is deposited on the walls, forming a film which is blown along the manifold by the air stream. Some of the droplets remain in the vapor-air stream and reach the cylinders.

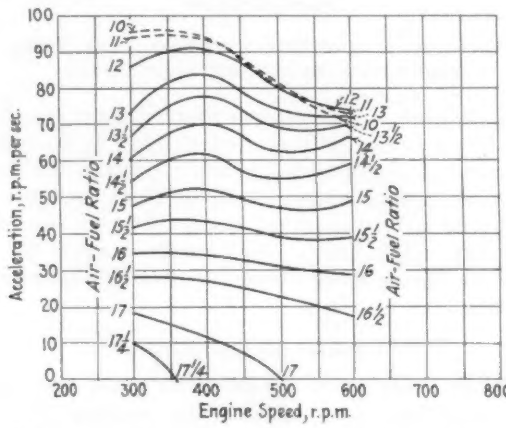


FIG. 13—COMPUTED ACCELERATION FOR VARIOUS AIR-FUEL RATIOS

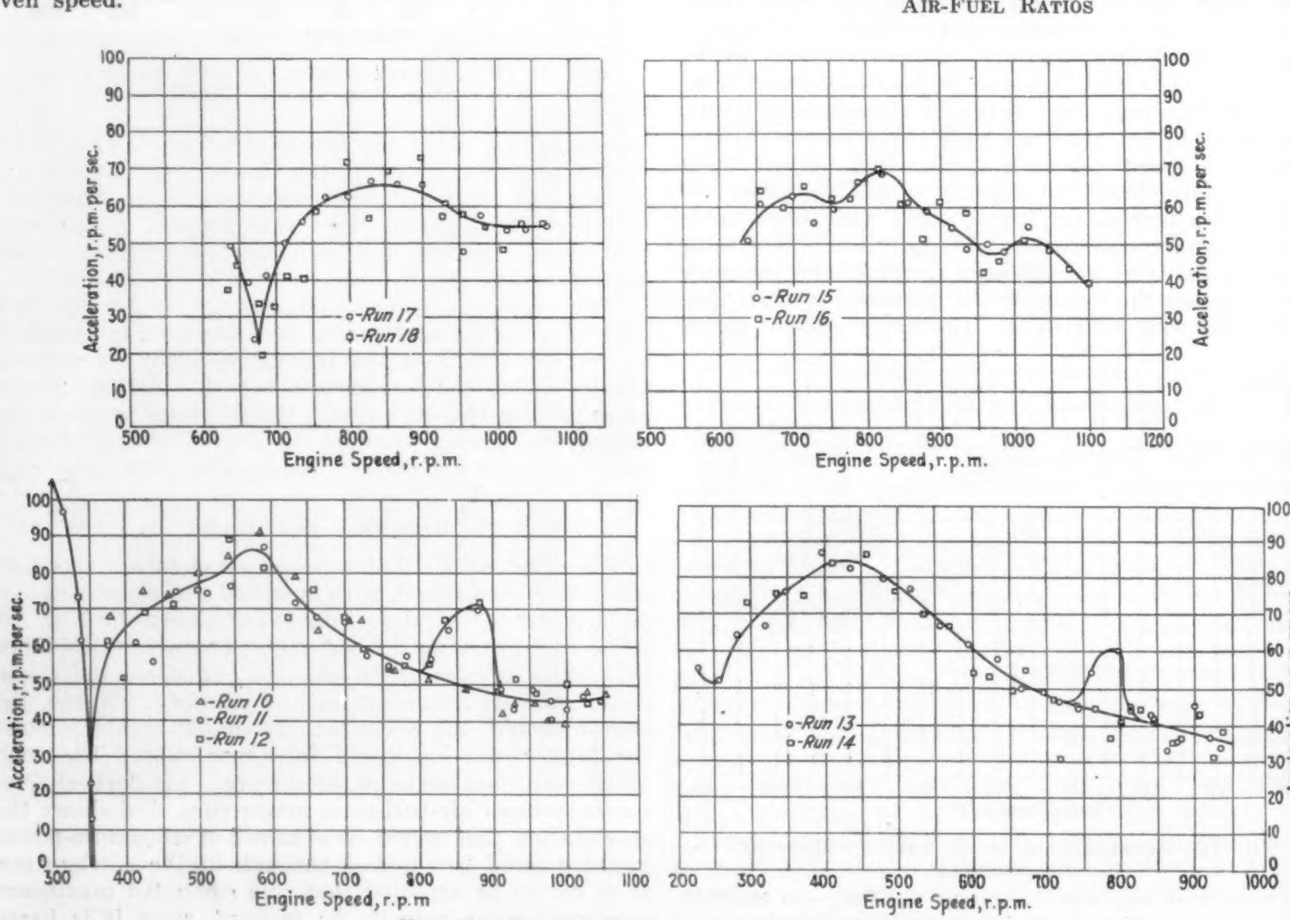


FIG. 12—CHARTED RECORDS OF INDIVIDUAL RUNS

At the end of 3 sec., in this case, a liquid film has covered the interior wall of the manifold to a depth of about 0.1 mm. and is beginning to blow into the cylinders, resulting in a greater ratio of fuel leaving the manifold to that of fuel entering the manifold, with consequent greater acceleration.

As the engine speed increases, air speed in the manifold increases; causing finer subdivision of the fuel droplets and resulting in a greater amount of fuel reach-

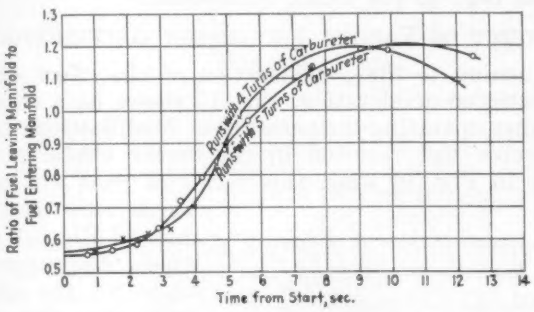


Fig. 14—Manifold Behavior with Different Carbureter Settings

ing the cylinders without being deposited on the walls. In addition, there is a greater tendency to blow the liquid film along the manifold wall. Six seconds after the start the fuel ratio reaches unity, indicating that exactly as much fuel is leaving the manifold as is entering it. Still later the ratio further increases, indicating that the increasing air-speed has resulted in blowing off some of the liquid film previously deposited on the manifold wall. This latter action theoretically would

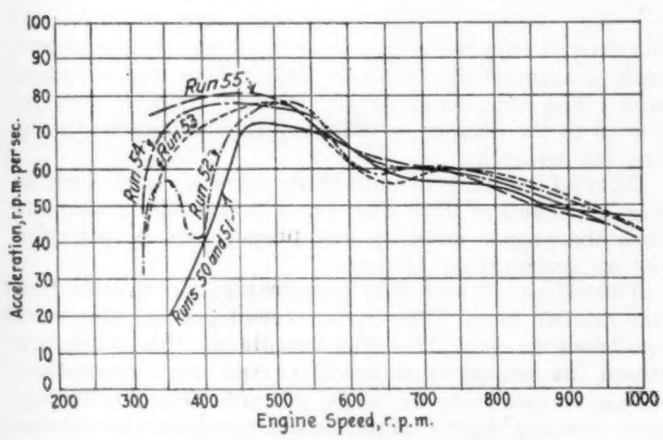


Fig. 15—Effect of Mixture Ratio

Conditions for the various runs were as follows:

Run No.	Carbureter Setting, Turns	Average Air-Fuel Ratio
50-51	2.5	14.8
52	2.8	13.6
53	3.0	12.8
54	3.5	11.3
55	4.5	10.0

continue so long as any increase in speed occurs; since for each engine speed there is what may be called an equilibrium thickness of film such that, under the drag of the air-stream speed obtaining at that engine-speed, liquid flow along the walls just suffices to discharge into the cylinders an amount of fuel equal to that deposited on the walls as spray. Practically, however, the chart under consideration shows this condition to be approxi-

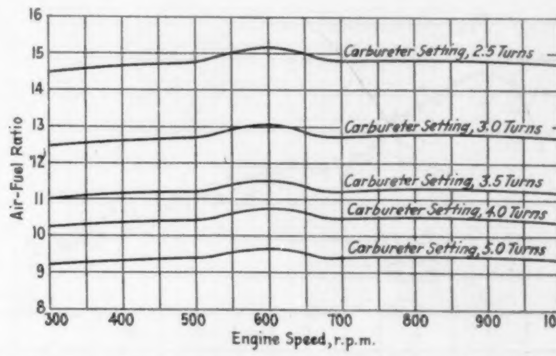


Fig. 16—Carbureter Characteristics with Various Settings

mated at the end of the acceleration. This, then, is believed to account for the larger deviations of the acceleration curves from the computed maximum acceleration.

It is interesting, although probably not significant, that, when the curves of Fig. 14 are extrapolated to zero time, the values of the ratio obtained are almost exactly equal to the equilibrium per cent vaporized under these conditions, as obtained by Dr. O. C. Bridgeman from the standard A.S.T.M. distillation of this fuel[10]. At 600

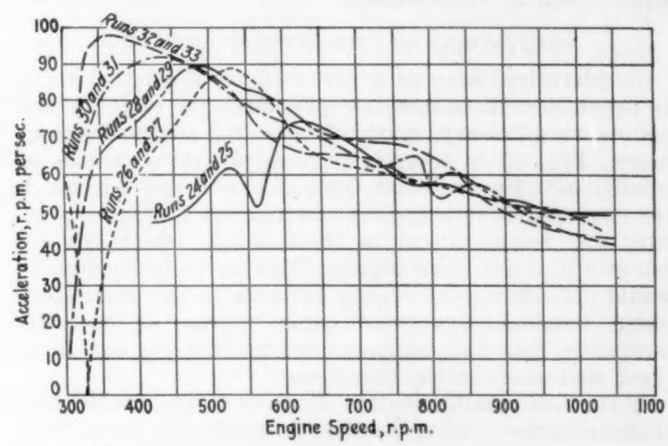


Fig. 17—Effect of Manifold Temperature

The Centigrade Temperatures Were as Follows:

Run No.	Manifold	Jacket	Charge
24-25	30	30	23
26-27	46	30	30
28-29	61	30	41
30-31	81	30	50
32-33	87	30	54

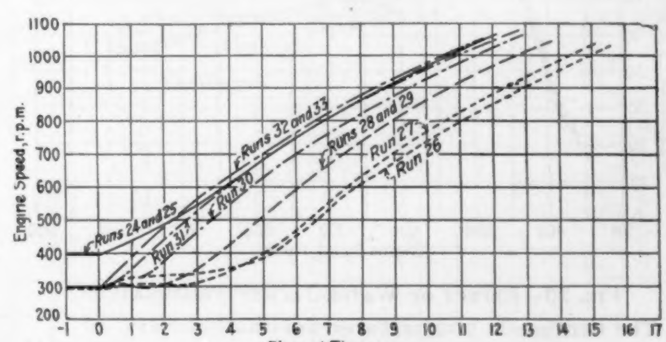


Fig. 18—Effect of Manifold Temperature

These Are Speed-Time Curves for the Same Runs As Are Represented by the Acceleration-Speed Curves of Fig. 17. The Volumetric Efficiency Seems To Fall Off More at High Speed

[10] See The Journal, April, 1928, p. 437.

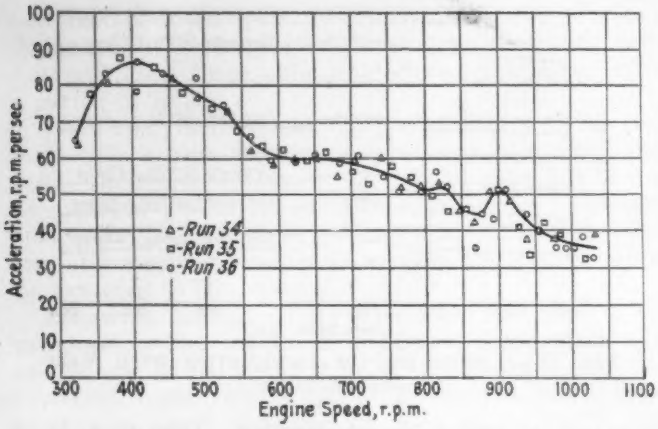


FIG. 19—RUNS WITH INCREASED WATER-JACKET TEMPERATURE

r.p.m. initial speed, however, the ratio found from the curves exceeds that obtained by Dr. Bridgeman by about 7 per cent, indicating the carrying of fuel as spray, at least at this speed. It seems likely that the close agreement at 300 r.p.m. is fortuitous and results from compensation by fuel spray for non-attainment of equilibrium in vaporization.

LIMITATIONS OF THIS METHOD OF STUDY

Acceleration, even at a given effective air-fuel ratio, is dependent on barometric pressure, air temperature, volumetric efficiency, spark advance, and engine friction; hence, Fig. 13 is correct for only a limited range of conditions. Furthermore, even if the data from which the chart is constructed are obtained at the same pressure and temperatures as those under which the acceleration is run, the accelerations actually obtainable would not correspond exactly to those in the chart computed from constant-speed runs because of the difference in internal engine-conditions between constant-speed and acceleration operation.

A further possible source of error is the probability of distribution during acceleration differing from that during constant-speed operation. From tests, it is concluded that this factor is not a serious one.

[11] See THE JOURNAL, March, 1924, p. 267.

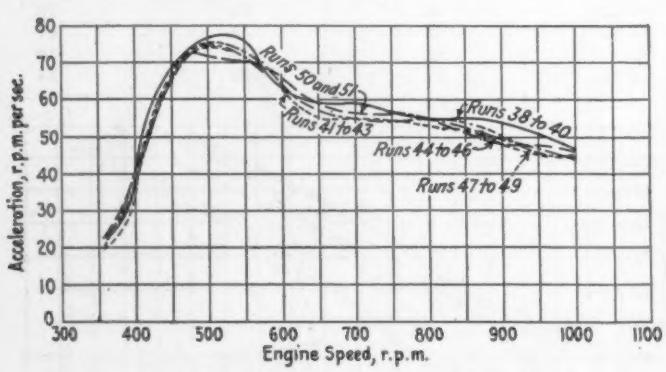


FIG. 20—EFFECT OF WATER-JACKET TEMPERATURE

The Centigrade temperatures were as follows:

Run No.	Jacket	Manifold
38-40	30	83
41-43	45	83
44-46	60	83
47-49	80	83
50-51	98	83

For these reasons, consistent values of air-fuel ratio in the vicinity of maximum power cannot always be obtained; imaginary air-fuel ratios are sometimes encountered. However, at lower accelerations, values accurate to about 0.5 unit can certainly be obtained. Fortunately, it is under these conditions that the greatest interest attaches to the results.

The error introduced in measuring the acceleration is negligible in comparison with other errors, being about 0.5 per cent of the brake horsepower.

EFFECT OF VARIOUS FACTORS ON ACCELERATION

Returning to the consideration of the effect of air-fuel ratio on acceleration, Fig. 15 shows data obtained at higher operating-temperatures. Modifications in the carbureter had resulted in carbureter characteristics shown in Fig. 16 when this series of runs was made.

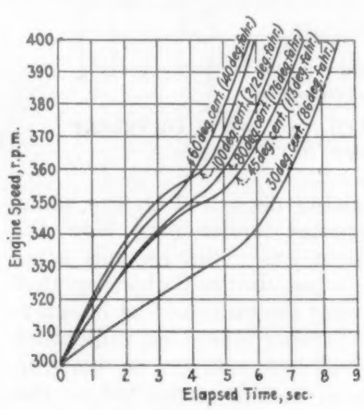


FIG. 21—SPEED-TIME PLOT

These runs resemble those of Fig. 10, when due allowance is made for the altered carbureter-characteristics. In general, increasing the richness reduces the initial lag, but beyond a certain point it results in poorer performance at higher speeds. At these operating conditions, a setting giving an air-fuel ratio of 13 to 1, plus a proper amount of accelerating charge injected at a proper rate, would give practically maximum performance throughout the acceleration. The conclusions of Mr. Birdsell[11], which were reported to the Society in 1924, are thus supported by the present research.

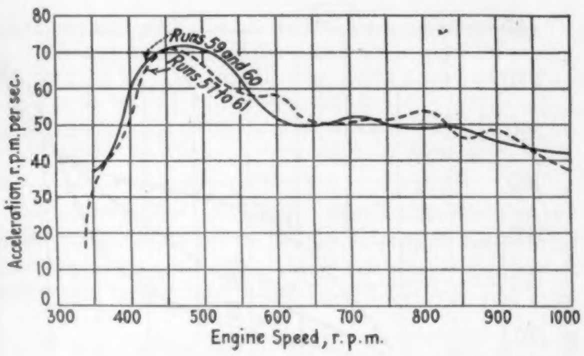
It is of interest to note that, from a chart such as Fig. 14, together with Fig. 11, it is possible to compute both the proper quantity and proper rate of injection for an accelerating charge.

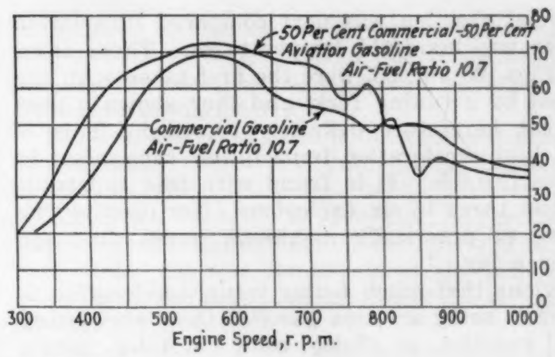
The effect of manifold temperature on acceleration was studied next. The carbureter-characteristics were as shown in Fig. 11. The results of this work are shown as acceleration-speed curves and speed-time curves, respectively in Figs. 17 and 18. At 30-deg. cent. (86-deg fahr.) manifold-temperature the engine would not accelerate from 300 r.p.m.; hence, runs of this set were started from 400 r.p.m.

The principal effect of increasing the manifold temperature is the same as that of increasing the richness of the mixture, that is, to reduce the initial lag. In addition, acceleration at lower speeds is greatly improved. Improved vaporization is believed to account for this. As the higher speeds are reached, the runs at lower manifold-temperatures show better acceleration than those at higher temperatures. Lower volumetric-efficiency at higher manifold-temperatures, as well as overrichness due to greater vaporization, is the probable cause of this effect.

JACKET TEMPERATURE INCREASED

Immediately after completing this series of runs the three runs shown in Fig. 19 were made, the manifold





ACCELERATION WITH DIFFERENT FUELS

Fig. 22—Runs 57 to 61 Were Made with 12.1 Parts of Air to 1 Part of U. S. Motor Gasoline *A*. Runs 59 and 60 Were Made with 12.53 Parts of Air to 1 Part of the 50-Per Cent Mixture of Aviation Gasoline

Fig. 23—Acceleration-Speed Curves of Runs 65 to 70, with Air-Fuel Ratio of 10.7 to 1. Speed-Time Curves for the Same Runs Are Plotted in Fig. 24, Which Shows the Consistency of the Results by the Smoothness of the Curves

temperature being nearly the same as in the last of the manifold temperature series, but with the jacket temperature raised from 30 to 100 deg. cent. (86 to 212 deg. fahr.). The considerably poorer acceleration obtained is thought to be due chiefly to decreased volumetric efficiency, as it is of the right amount to be accounted for by this effect. In this connection it should be noted that these runs were made with a rather rich mixture, leading to considerable dilution of the oil on the cylinder-walls. For this reason, engine friction might be expected to be nearly the same at both jacket-temperatures.

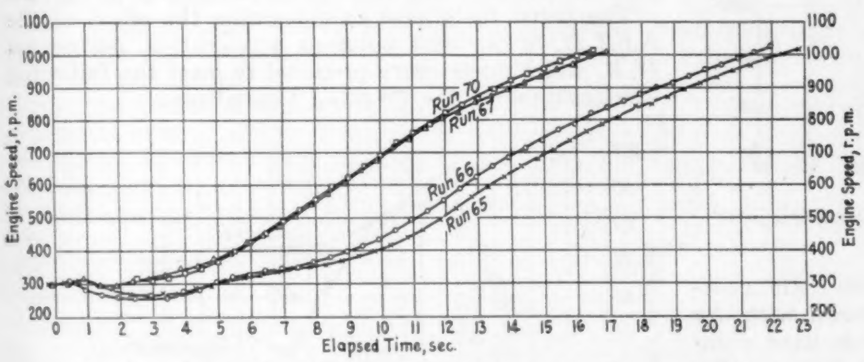


FIG. 24—SPEED-TIME CURVES WITH DIFFERENT FUELS; SERIES 2

The effect of jacket-water-temperature on acceleration is shown in Fig. 20. In these and all subsequent runs, carbureter characteristics are those shown in Fig. 16. Although the five sets of runs here shown lie nearly within the limits of error of observation, increasing the jacket temperature evidently tends to decrease the acceleration. This agrees qualitatively with the result stated in the previous paragraph, although not quantitatively if the entire responsibility for the change is assigned to volumetric efficiency. Since the runs here considered were made with a very lean carbureter-adjustment, less dilution of oil on the cylinder-walls is to be expected than in the case of the runs mentioned above. Engine friction would therefore be greater at low than at high jacket-water-temperature. The net effect of these two opposing factors, volumetric efficiency and engine friction, is considered responsible for the results shown in Fig. 20.

A speed-time plot of this series of runs is shown in Fig. 21. The runs at 60 deg. cent. (140 deg. fahr.) are not consistent with the rest of the series, which shows a general trend toward shorter initial-lag as the jacket-water-temperature is increased.

The ultimate object of this line of work was a study of the effect of the A.S.T.M. 50-per cent point on acceleration; however, because of the rather limited supply of special fuels for this purpose, preliminary work was done on aviation, commercial and blended fuels to select suitable conditions for the study of the 50-per cent-point fuels.

The curves shown in Figs. 22 and 23 were obtained with commercial gasoline and a blend composed of equal parts of commercial and aviation gasoline. A difference in the air-fuel ratio used impairs the value of the comparison in Fig. 22, but the general observation that less difference is shown between different fuels at higher manifold-temperatures is supported by subsequent work. Fig. 24 shows the data used in Fig. 23, plotted as speed-time curves. This figure is inserted to show the extent to which the results can be reproduced.

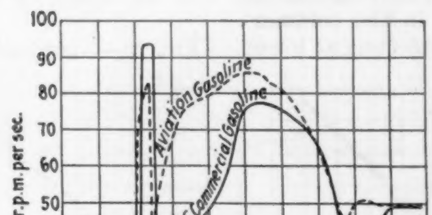


FIG. 25—ACCELERATION WITH DIFFERENT FUELS; SERIES 3

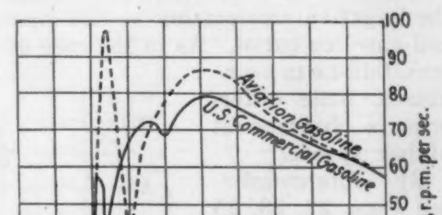


FIG. 26—ACCELERATION WITH DIFFERENT FUELS; SERIES 4

Commercial gasoline was next compared to aviation gasoline, at two manifold temperatures. These runs, shown in Figs. 25 and 26, were the first taken with the spark timed by a tuning fork, and they shown a phenomenon not heretofore definitely recorded. This is the initial high-acceleration immediately consequent to opening the throttle. It is found with this apparatus that the first three to six explosions after opening the throttle are of practically maximum power, and are followed by a lag.

It is obvious that much better initial-acceleration is obtained when using aviation gasoline than when using commercial gasoline, at 33-deg. cent. (91.4-deg. fahr.)

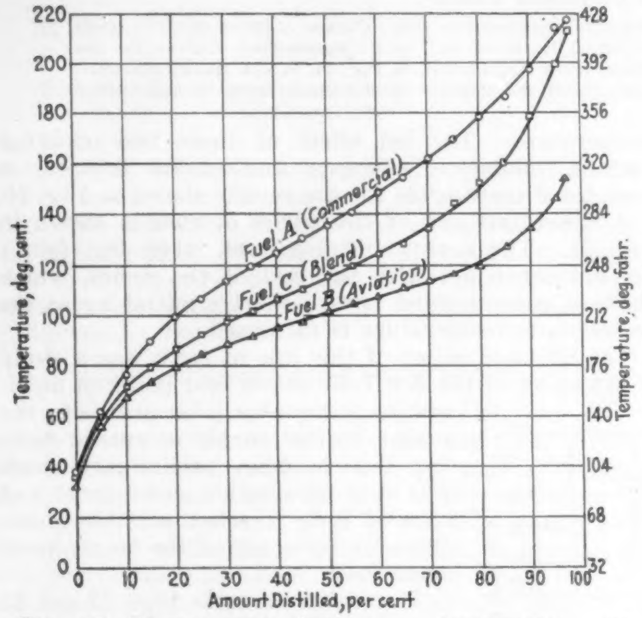


FIG. 27—DISTILLATION CURVES OF COMMERCIAL AND BLENDED FUELS

manifold-temperature. However, above 650 r.p.m. practically no difference in acceleration is shown with the two fuels. As a higher electrical-load was used unintentionally, in making the tests of Fig. 25, these results cannot be compared directly with others. At a manifold temperature of 92.5 deg. cent. (198.5 deg. fahr.) less difference is shown, and such difference as does exist is partly masked on Fig. 26 by the difference in speeds at which the initial lag occurs. Thus, the drop in the aviation-fuel curve at 350 r.p.m. corresponds to the negative acceleration at 320 r.p.m. in the commercial-gasoline curve. As in the case of the runs at lower manifold-temperatures, little difference is observed at higher speeds.

By intercomparing Figs. 22, 23, 25 and 26 it is seen that use of this blend of aviation and commercial gasoline does not give half the improvement over commercial gasoline that the use of aviation gasoline does. Distillation curves for these three fuels are shown in Fig. 27.

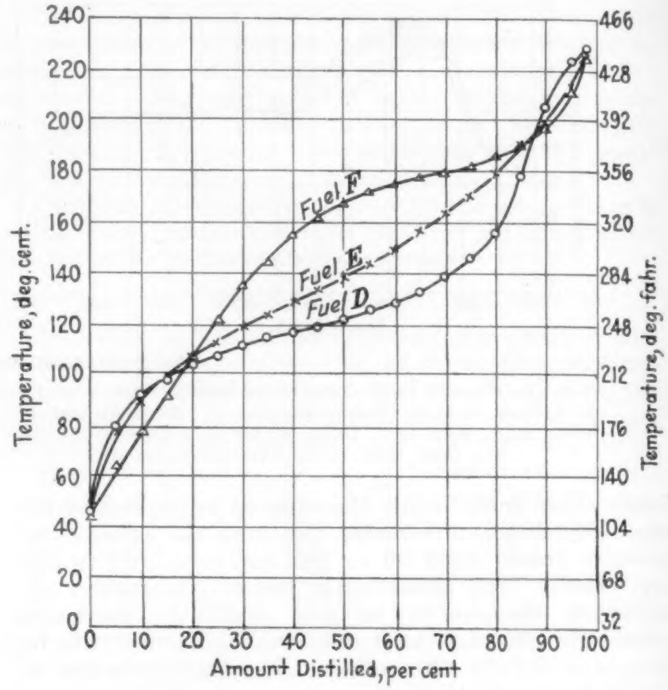


FIG. 28—DISTILLATION CURVES OF SPECIAL TEST-FUELS

The three fuels used to determine the effect of the A.S.T.M. 50-per cent point on acceleration, designated *D*, *E*, and *F* fuels, were prepared to meet the following specifications of the Steering Committee:

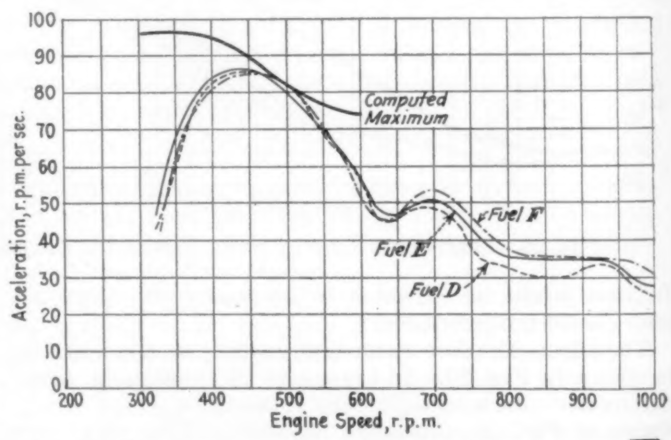


FIG. 29—ACCELERATION WITH DIFFERENT FUELS; SERIES 5

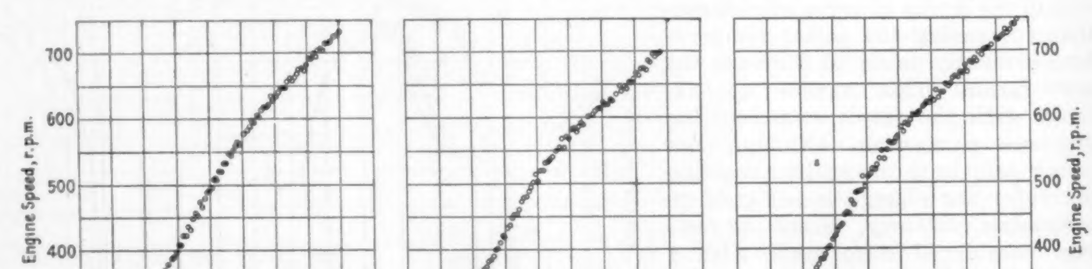


FIG. 30—SAMPLE SPEED-TIME CURVES

> Initial boiling-points to be within a range of 20 deg. fahr., with approximately the same recovery; 20-per cent points to be 220 to 222 deg. fahr.; and 90-per cent points to be 391 to 393 deg. fahr.
>
> Temperatures for 50-per cent evaporation, in degrees fahrenheit: Fuel *D*, 248; fuel *E*, 284; fuel *F*, 326.

Fig. 28 shows the A.S.T.M. distillation-curves of these fuels at the time when the acceleration tests were run, more than one year after these fuels were prepared. Originally, the agreement with specifications was even closer.

The first tests made on *D*, *E*, and *F* fuels are shown in Fig. 29. Sample speed-time curves, taken from the test runs of this series, are shown in Fig. 30. These tests were made with cylinder-jacket water at 96 deg. cent. (204.8 deg. fahr.), inlet-manifold jacket at 32 deg. cent. (89.6 deg. fahr.), and the carbureter set at 3.75 turns. These conditions are such as to give very poor vaporization in the manifold—less than 50 per cent, judging by the acceleration during the initial lag.

Each curve shown in Fig. 29 is the mean of four test-runs. Up to 650 r.p.m., such differences as are shown are within the limits of experimental error. Above that point, however, the differences are thought to be real and to indicate differences in effective volatility, inasmuch as these speeds are in the region of overrichness due to initial loading of the manifold. In connection with these runs, and in contrast to the next series of tests on *D*, *E*, and *F* fuels, it is to be noted that the speed-time curves for this series do not show any consistent difference in initial lag with the different fuels.

It was desired to have a further check on these results and, if possible, to correlate them with tests made on aviation, commercial, and the 50-per cent blend of aviation and commercial gasolines. Therefore a second series of tests was run, comparing the aviation fuel with *D*, *E*, and *F* fuels. This series of tests was made under the same controlled-conditions as those of the runs shown in Fig. 23, but direct comparison of the two series is vitiated by a large difference in barometric pressure between the two tests and, apparently, a small difference in engine friction.

This test series was run with cylinder-jacket water at 88 deg. cent. (190.4 deg. fahr.), inlet-manifold jacket at 43 deg. cent. (109.4 deg. fahr.), and carbureter set at 3.0 turns. It will be seen that, under these conditions, a greater percentage of the fuel will be vaporized than under the test conditions of the previous series, due to both the hotter manifold and the leaner supplied-air-fuel ratio.

The acceleration-speed curves of this series are shown in Fig. 31, while curves and data for the individual fuels are plotted in Figs. 32 to 35. Aviation gasoline, naturally, shows much the best acceleration. Decided and seemingly haphazard differences now show in the curves for *D*, *E*, and *F* fuels, each of which at some speed shows better acceleration than either of the other two at the same speed. Above 580 r.p.m., however, the fuels are arranged in the order of their 50-per cent-point volatilities; that is, in the inverse order of their 50-per cent-point temperatures.

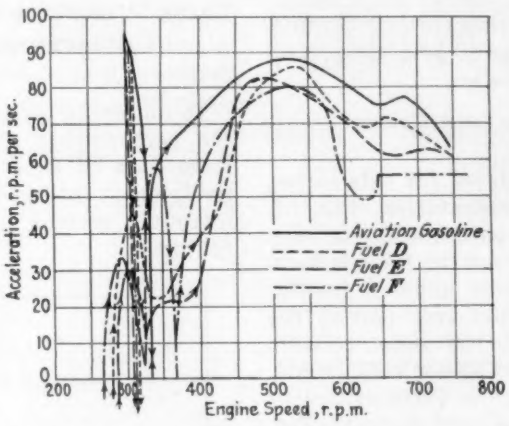
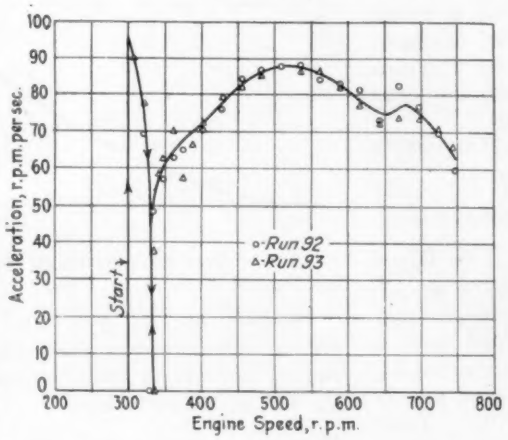
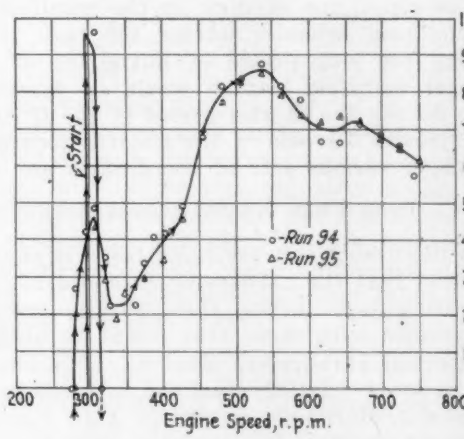
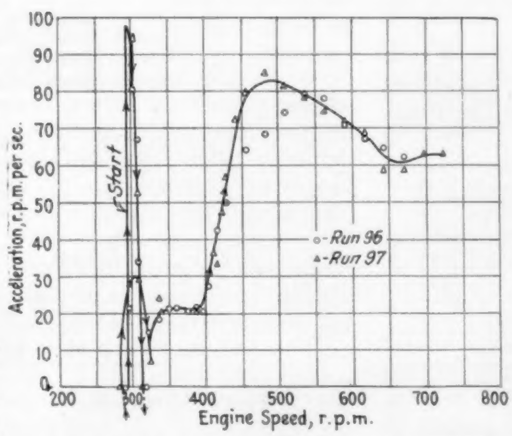
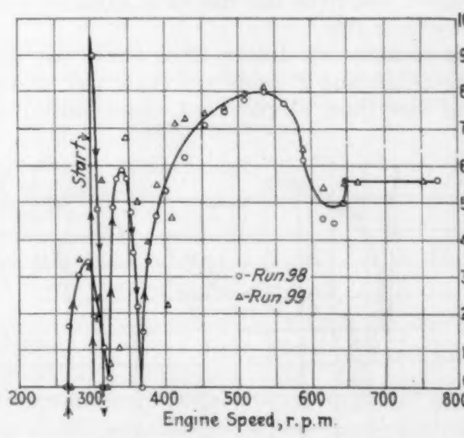


Fig. 31—Aviation Fuel Compared with Special Fuels









Individual Curves Included in Fig. 31

Fig. 32—Acceleration with Aviation Gasoline

Fig. 33—Acceleration with *D* Fuel

Fig. 34—Acceleration with *E* Fuel

Fig. 35—Acceleration with *F* Fuel

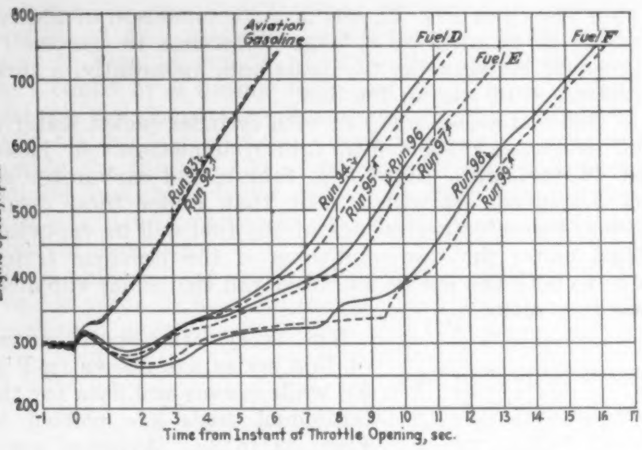


FIG. 36—COMPARATIVE SPEED-TIME CURVES

On considering the speed-time curves for this series, Fig. 36, or the more accurate representation, Fig. 37, in which acceleration is plotted against time, a very consistent and definite relation between the fuels is seen. The initial lag, under these conditions, appears qualitatively to be a function of the 50-per cent points, the differences in initial lag being of the same relative magnitudes as the differences in the 50-per cent points. These charts further suggest that the peculiarities in the acceleration curves for the D, E and F fuels, Fig. 31, are the results of the previous history of the individual acceleration run; that is, they are attributable to the conditions existing in the manifold as a result of the past behavior during the run. For example, during the long period of initial lag of the F runs, greater manifold loading would be expected to occur than during the shorter period of the D runs.

Appendix 3 treats of the relative accuracy of charts in which various sets of coordinates are used.

POOR FUEL NEEDS ACCELERATING WELL

In discussing this series of tests, it should be borne in mind that the carbureter used did not have an accelerating well: hence, these results are not directly comparable with those that might be obtained with a commercial carbureter. That is, with an accelerating well, a lower-volatility fuel can be made to give nearly as good performance as one of high volatility. This, of course, requires the use of a greater quantity of the lower-grade fuel.

The conclusions drawn from these two series of tests on the D, E, and F fuels are that, (a) under conditions giving less than 50-per cent vaporization in the manifold, there is little effect of differences in the A.S.T.M. 50-per cent point with fuels having like 20-per cent points; and, (b) under conditions giving slightly more than 50-per cent vaporization in the manifold, the primary influence of the A.S.T.M. 50-per cent point is shown chiefly in the initial lag, although some variations in acceleration are indicated. It should be noted that the vaporization during acceleration may depart widely from equilibrium conditions; and, therefore, equilibrium air-distillation data are not directly applicable.

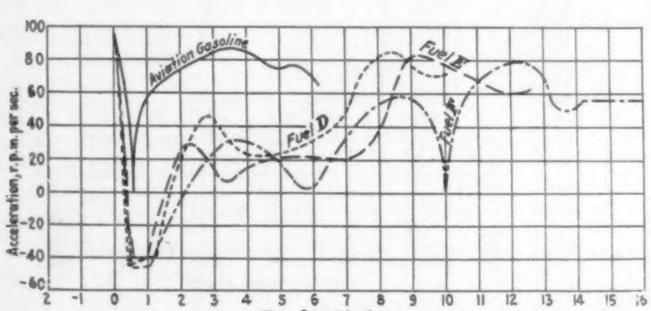


FIG. 37—COMPARATIVE ACCELERATION-TIME CURVES

APPENDIX

ERROR INTRODUCED BY NUMERICAL DIFFERENTIATION OF DISPLACEMENT-TIME DATA FOR SPEED AND ACCELERATION

In obtaining an acceleration-speed curve representing the performance of the engine considered as a unit, from data of time and displacement observed at relatively short intervals, numerical differentiation does not introduce serious error. This can be demonstrated as follows:

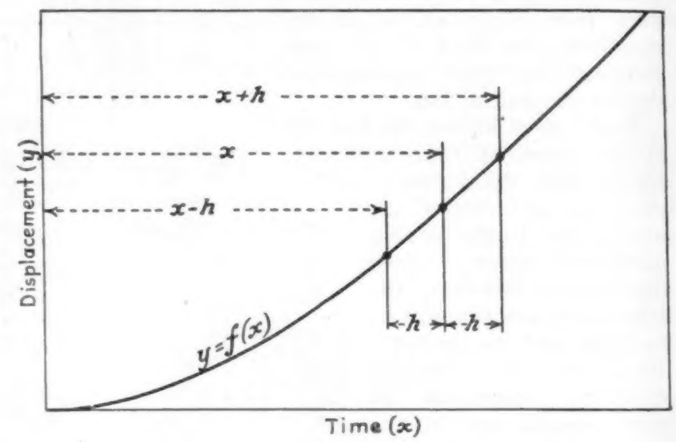


FIG. 38—DIAGRAM OF DIFFERENTIATION

In Fig. 38, let $y = f(x)$ be the displacement-time curve, and points at abscissas $x - h$, x, and $x + h$ represent successive measurements, whose values are y_1, y_2, and y_3 respectively.

Let

A = mean acceleration from S_1 to S_2
S = mean speed from $x - h$ to $x + h$
S_1 = mean speed from $x - h$ to x
S_2 = mean speed from x to $x + h$

Then

$$S = \frac{y_3 - y_1}{2h} = \frac{f(x+h) - f(x-h)}{2h} \qquad [1]$$

$$S_2 = \frac{y_3 - y_2}{h}$$

$$S_1 = \frac{y_2 - y_1}{h} \text{ and}$$

$$A = \frac{y_3 - 2y_2 + y_1}{h^2} = \frac{f(x+h) - 2f(x) + f(x-h)}{h^2} \qquad [2]$$

By Taylor's Theorem

$$f(x+h) = f(x) + f_1(x)\,h + \frac{f_2(x)\,h^2}{2\,!} + \frac{f_3(x)\,h^3}{3\,!} + \frac{f_4(x)\,h^4}{4\,!} + \frac{f_n(x)\,h^n}{n\,!} \qquad [3]$$

$$f(x-h) = f(x) - f_1(x)\,h + \frac{f_2(x)\,h^2}{2\,!} - \frac{f_3(x)\,h^3}{3\,!} + \frac{f_4(x)\,h^4}{4\,!} - \cdots + \frac{f_n(x)\,h^n}{n\,!} \qquad [4]$$

Differencing

$$f(x+h) - f(x-h) = 2f_1(x)\,h + \frac{2\,f_3(x)\,h^3}{3\,!} + \frac{2f_5(x)\,h^5}{5\,!} + \cdots + \frac{2\,f_{2n+1}(x)\,h^{2n+1}}{(2n+1)\,!} \qquad [5]$$

Dividing by $2h$ and transposing

$$f_1(x) = \frac{f(x+h) - f(x-h)}{2\,h} - \frac{f_3(x)\,h^2}{3\,!} - \frac{f_5(x)\,h^4}{5\,!} - \cdots - \frac{f_{2n+1}(x)\,h^{2n}}{(2n+1)\,!} \qquad [6]$$

in which $f_1(x)$ is the true speed at x, $[f(x+h)-f(x-h)]\div 2h$ is the result of numerical differentiation of the data for the mean speed from $x-h$ to $x+h$, as shown in (1) above, and the remaining terms are the difference between the two, and may be used, as desired, either to correct the result of numerical differentiation or to calculate the error thus introduced.

To obtain similar information on acceleration values, (3) and (4) above are added, giving

$$f(x+h) + f(x-h) = 2f(x) + \frac{2f_2(x)\,h^2}{2\,!} + \frac{2f_4(x)\,h^4}{4\,!} + \cdots + \frac{2f_{2n}(x)\,h^{2n}}{2n\,!} \qquad [7]$$

Transposing

$$\frac{2f_2(x)\,h^2}{2\,!} = f(x+h) - 2f(x) + f(x-h) - \frac{2f_4(x)\,h^4}{4\,!} - \cdots - \frac{2f_{2n}(x)\,h^{2n}}{2n\,!} \qquad [8]$$

Dividing by h^2

$$f_2(x) = \frac{f(x+h) - 2f(x) + f(x-h)}{h^2} - \frac{2f_4(x)\,h^2}{4\,!} - \cdots - \frac{2f_{2n}(x)\,h^{2n-2}}{2n\,!} \qquad [9]$$

in which $f_2(x)$ is the true acceleration at x, $[f(x+h)-2f(x)+f(x-h)]\div h^2$, is the result of double numerical differentiation for the mean acceleration from S_1 to S_3 as shown in (2) above, and the remaining terms represent the error introduced in obtaining an approximate value for acceleration by double numerical differentiation.

Obviously, decreasing h, the time interval, reduces the inaccuracy of both the speed and the acceleration values obtained. Also the error introduced in acceleration values is a function of the radius of curvature of the acceleration curve, decreasing with increasing radius of curvature. Hence, it is greatest at the point where the acceleration curve changes *direction* most rapidly. Similarly the greatest error in speed values is introduced when the acceleration is changing in *magnitude* most rapidly.

Since double numerical differentiation of the cubic is exact, as shown by (9), the error caused by double numerical differentiation in any case is a measure of the departure of the empirical curve from cubic.

To illustrate the magnitude of the error thus introduced, computation has been made for an acceleration curve similar to that of commercial gasoline in Fig. 25.

[12] See Graphical and Mechanical Computation, first edition, p. 256, John Wiley & Sons, Inc., New York.

The greatest error found to be introduced in the acceleration values, assuming 1 sec. time intervals, is 0.03 r.p.m. per sec.; while the greatest error in speed is found to be 0.6 r.p.m., neither of which is at all serious. As h, the time interval, is reduced, both of these errors rapidly diminish.

In reducing observations made with the tuning fork, however, double numerical differentiation has been found impractical, since, in the short time-interval between observations, 0.07 or 0.04 sec., the acceleration is of the order of magnitude of the experimental error due to spark wandering. These data therefore are plotted against speed-time coordinates, and tangents are constructed to the smooth curve through the plotted points. A method for drawing such tangents is described in a book by Dr. Joseph Lipka[12].

APPENDIX 2

Error in Measurement of Pulsating Air-Flow by Thin-Plate Orifices

When orifices are used in measuring air-flow to an engine, an error is introduced in the results, because of pulsation. In other words, the steady-flow formula does not apply satisfactorily to pulsating flow. The following data, taken on the six-cylinder engine used in this work, will illustrate this point. Every engine condition was maintained unaltered during these tests, only the orifice diameter being changed.

Orifice Diameter, In.	Head, In. of Water	Computed Air-Flow, Lb. per Hr.	Error Based on 1-In. Orifice, Lb. per Hr.
1	0.982	59.0	0.0
1½	0.214	61.6	2.6
2	0.101	74.8	15.8
3	0.065	133.8	74.8

Various considerations lead to the belief that the value obtained with the 1-in. orifice is substantially correct. On this basis, the error diminishes as the head increases, as would be expected, since steady flow is more nearly approximated under the higher heads.

Mention is made of this point to call attention to possible constant errors in the air-fuel-ratio values stated herein. Every precaution has been taken to reduce such errors to the minimum.

APPENDIX 3

Graphical Representation of Acceleration Data

Of the six possible sets of coordinates which might be utilized in the graphical representation of data pertaining to engine acceleration, only one, that in which speed is plotted against time, has been used heretofore in papers describing the progress of this research. The possible sets of coordinates are:

(1) Displacement versus time
(2) Speed versus time
(3) Acceleration versus time
(4) Speed versus displacement
(5) Acceleration versus displacement
(6) Acceleration versus speed

Speed-time coordinates are satisfactory for the qualitative discussion of data; they show the initial lag phenomena well, and continued usage has made them readily understandable. Acceleration may be inferred to within about 25 per cent from the inspection of the slope of the curve.

To permit quantitative discussion of the acceleration

data, however, they must be expressed as acceleration versus either speed or time. Best results will be obtained by the use of both forms in conjunction. Thus, in the initial-lag period, time, reckoned from the instant of opening the throttle, is the major factor influencing the acceleration; beyond that region, engine characteristics variable with speed exert the preponderant influence on the acceleration. For these reasons, more information is given by acceleration-time curves in the region of initial lag, and by acceleration-speed curves beyond the initial lag.

Displacement-time, speed-time, and speed-displacement curves are of interest primarily in connection with the road performance of cars.

THE DISCUSSION

F. C. MOCK[13]:—The subject of fuel research is of particular interest to my company, and the paper by Mr. Brooks checks closely with our observations and experience. We have tried in the course of our work different fuels, ranging in volatility from common automobile-fuel to high-test fuels and aviation gasoline. During the winter we experience with our engines the same difficulty with aviation gasoline that Mr. Brooks has demonstrated, but less than with standard fuel.

It therefore seems plain that no economically practical change in fuel volatility will enable present engines to accelerate properly under all conditions with carbureter and manifold systems which give proper mixture-proportions only for steady running under steady load. In further comparisons of fuels, accordingly, is it not desirable to take into account the means available for obtaining satisfactory acceleration and to determine the requirements of fuel volatility under these conditions?

From the information submitted by Mr. Brooks, it is apparent that there are three main ways of obtaining satisfactory acceleration with an economical steady-running mixture-proportion, using fuels of present volatility, namely:

(1) To raise the air velocity through the carbureter and inlet manifold so that it never falls below a certain minimum, which will be between 30 and 70 ft. per sec. The only practical demonstration so far made in this direction is in the so-called cold carburetion, and I cannot say what results can be obtained with this in regard to minimum and maximum velocities, avoiding power loss at high speed, and obtaining good operation without application of heat to the charge.

(2) If the air entering the carbureter could be maintained at all times at 160 deg. fahr., satisfactory acceleration would, I believe, be obtained with normal steady-running mixture-proportions from the carbureter. This probably can be done, although I know of no instance in which it has been even approximated. It would require an air-heater of elaborate construction, of volume at least equal to that of the exhaust manifold, and having a thin wall of low heat-capacity between the exhaust and the air to be heated. It would also require a very large, thermally regulated, automatic cold-air valve, and heat-insulating protection between the carbureter and the heater.

The temperature of 160 deg. fahr. is near the initial boiling-point of the fuel, and, as the carbureter body would tend to reach this temperature in the summer, there would be a very close temperature-margin between satisfactory operation and boiling of the fuel in the carbureter jets. A slight edge of the performance on hills might be taken off by this heating of the charge. With the regulation outlined, the mixture temperature might reach 150 deg. fahr. in the summer with no application of the exhaust heat to the inlet manifold, because of the heat under the hood; whereas, with our common exhaust-hot-spot manifolds and with heat control, the mixture temperature on a hot day in summer is sometimes 180 deg. fahr. or higher. Note that maintaining either a high manifold-velocity or a high entering-air temperature requires an elaborate and expensive departure from present constructional practice.

(3) A temporary enrichment of the mixture, or "accelerating charge," can be delivered from the carbureter. This is useful at temperatures and with fuels of volatilities such that the deficiency in momentary vaporization can be compensated for by a reasonable enrichment of the mixture. If the temperature is too low or the fuel is lacking in lighter elements, the amount of accelerating charge required will be very great and, if supplied, will give "loading" in the inlet manifold as the engine picks up speed.

Devices of this sort now are found in all the better-grade American carbureters and seem to be fairly effective. The chief difficulty experienced with them is that the amount of accelerating charge required, as Mr. Brooks has shown, is largely a matter of temperature.

Speaking from our own practice, we find that—for a 250-cu. in. engine, on a hot day in summer, with standard fuel, after fast driving—no accelerating charge is required; in fact, 0.10 cc. (0.006 cu. in.) of accelerating charge, whether fed fast or slowly, will cause the engine to stumble and miss when the throttle is opened. The same engine in the winter will accelerate best with an accelerating charge of perhaps 3 cc. (0.183 cu. in.). With aviation gasoline this same amount of fuel charge is not detrimental in the winter, but during the spring or fall the accelerating charges need to be diminished with lighter fuels. The amount of accelerating charge required varies also according to various conditions.

I should like to suggest that it will be of value if Mr. Brooks will add data on the air velocities through the inlet manifold and carbureter for different engine-speeds. The acceleration lag so clearly varies with the manifold velocity that it would be illuminating to have this information.

DONALD B. BROOKS:—Air speeds through the inlet manifold at the engine starting-speeds and maximum-speeds used in these tests are as follows:

R.P.M.	300	400	600	1,000
Ft. per Sec.	26	34	50	85

[13] M. S. A. E.—Research engineer, Stromberg Motor Devices Co., Chicago.

Front-Wheel Drives, Are They Coming or Going?

By HERBERT CHASE[1]

SEMI-ANNUAL MEETING PAPER — *Illustrated with* PHOTOGRAPHS AND DRAWINGS

AFTER listing the advantages and disadvantages of front-wheel drive the author says that, although most American engineers who have given him their opinions seem to believe that the advantages of front-wheel drive are outweighed by its disadvantages, he has grounds for venturing the opinion that this form of drive is likely to have extensive use in this Country within the next few years. He bases this view more upon commercial than upon strictly engineering considerations; but the latter are not lacking altogether, as is evident from his subsequent analysis.

The advantages and the disadvantages are specifically and separately discussed, existing designs of front-wheel drive being divided into three classes. Numerous illustrations of the different types of front-wheel-drive vehicle are presented, and their most important features are enumerated and explained.

In conclusion the author says that, although there is good ground for the view that the advantages outweigh the disadvantages, it does not follow as a necessary corollary that front-drive cars will become the popular type or that they will be adopted soon by many manufacturers. Several companies are, however, greatly interested. Basically, nearly all American cars are very much alike in mechanical design and have undergone practically no major changes since the introduction of four-wheel brakes. We are about due for some radical changes in design, and it is not unlikely that one of these will be the front-wheel drive.

One of the discussers makes the point that, in the last 500-mile race, the troubles experienced with the front-wheel-drive racing cars could not be charged to the front-wheel drive itself. Another cites tests which disproved the claim that less power is required to propel a car by the front wheels than by the rear wheels. It is stated by another speaker that the failures of the supercharger drive-gears in the 500-mile race were mostly on cars having front-wheel drives. He says also that it is observable on the speedway that the front-wheel-drive cars spin their wheels much more than do the rear-wheel-drive cars at the same speed.

It is mentioned that front-wheel-drive cars follow the front wheels and have less tendency to skid on turns provided the driver has the courage to keep his foot on the throttle, but that this is a dangerous procedure. It is brought out also that the arrangements of independent wheel-springing and the reduction of unsprung weight can be applied equally well to front-wheel and to rear-wheel drives.

In conclusion, the author states the answers he received to the question: "What other major improvements do you consider more promising than front-wheel drives?"

THE front-wheel drive is reported to have been in actual use in 1862, and it was applied to gasoline-driven vehicles in the period from 1900 to 1905 if not before that time. This paper is therefore in part a review of automotive history, but certain fairly recent designs are also presented, as well as an analysis of the advantages and disadvantages of front-wheel drives in general which, it is hoped, will provide a useful background for those who contemplate a further study of the subject.

Unless otherwise stated, my comments apply especially to passenger-cars; but they apply also to motor-truck and to motorcoach chassis. One of the few original American designs shown has been applied in practice only to motorcoach chassis, but it appears to be adaptable also to passenger-cars and to motor-trucks.

Even a casual study of the accompanying statement of the advantages and disadvantages of front-wheel drive reveals some apparent inconsistencies. It must be noted, however, that some of both apply only to certain forms of construction while others apply not specifically to front-wheel drives in themselves but to attendant favorable or unfavorable conditions that could not well be realized without such a drive. Therefore, too narrow an interpretation should not be made, and it should be borne in mind that a factor set down as an advantage or disadvantage in one type of construction may be the reverse in dissimilar constructions.

THREE CLASSES OF FRONT-WHEEL DRIVES

Class 1.—This type embodies a front axle similar in general construction to a conventional rear axle but modified to accommodate steering-knuckles and provide a universal drive. It is used chiefly on four-wheel-drive trucks and possesses few of the advantages obtained in other types.

Class 2.—In this type the steering-knuckles are joined by a rigid member or members. The latter are unsprung in designs such as the Miller and the Marmon racing cars, but can be sprung as in the Tracta design. The differential and the bevel gears are carried, not by the dead axle, but on the frame; hence, they do not add to the unsprung weight.

Class 3.—The wheels and the knuckle pivots in this type are attached only to springs or distance-members, there being no "dead" axle in the ordinary sense. In designs such as the Alvis and the Itala, the wheels are completely independent in their springing. In the Healey-Aeromarine design, some reaction exists between the two wheels.

A mental picture of the three classes should be formed and kept in mind while the advantages and disadvantages already cited are discussed in detail.

[1] M.S.A.E.—Engineer, Erickson Co., Inc., New York City.

Discussion of Advantages

Unencumbered space for the body, (1), although not properly referring to the front-wheel drive itself, usually is mentioned as the most important of all benefits made possible by driving to front instead of to rear wheels. Such an estimate seems to be correct, for many of the body designers' handicaps are thereby eliminated. The frame can assume almost any desired shape. The absence of a bulky rear-axle and a long propeller-shaft connecting it to the gearset makes possible a very low floor and either a lower roof or one allowing more headroom. It is pointed out by J. G. Vincent, of the Packard Motor Car Co., however, that passenger-car bodies with conventional rear drives can be made so low that the passengers when seated have their eyes as near the ground as when walking, and that there seems to be no advantage in further lowering of the body. In fact, if the driver sits any lower, the cowl, the hood and the radiator prevent him from seeing the road as close to the front of the car as is desirable. But in motorcoaches and some forms of motor-truck the possibility of a lower platform presents evident advantages which, as we shall see, are put to good use in some designs.

Rear Axle Simplified

That a front drive simplifies greatly the problem of rear-axle construction, (2), will hardly be questioned. As in the Rumpler, Alvis and Healey-Aeromarine designs, it is possible to eliminate even a dead rear-axle and to carry the wheels on arms pivoted to the frame. In this case the unsprung weight is very small and the advantages, or the disadvantages, of independently sprung rear wheels are realized.

If preferred, rear wheels can be carried upon either a sprung rear-axle that can be cranked to lower the body platform or that can be made straight, or upon stub axles independently sprung and positioned by suitable guides. But in any case the bulk and the complication of a conventional live rear-axle are avoided. Whether the net result is merely to transfer the complication to the front of the vehicle is another question and depends in part upon the design employed. In most cases, however, the decreased complication in the rear axle is not a clear gain, for the front-drive axle seldom is as simple as the conventional "dead" type.

Decreased bulk in the rear axle is an advantage from the viewpoint of body design, especially in motorcoaches and to some extent in passenger-cars also, for the designer need not be hampered by the necessity for a recess under the rear portion of the body to prevent a bulky differential-housing from striking under maximum spring-deflections.

Improved Riding-Qualities

Improvement of riding qualities, (3), can be credited in large part to the lessened unsprung-weight. This decrease in weight of parts below the spring can be made a very material one, for the rear axle can be a relatively light forging or it can be dispensed with in favor of independent wheels such as are used in the Aeromarine and Alvis designs. The front wheels and axle sometimes are heavier than the conventional form, especially if those falling in Class 1 are used; but with those in Class 2 and some forms in Class 3, the unsprung weight is very small, one reason being that brake-drums often are carried on the chassis instead of on the wheels, while springs or distance-linkages sometimes displace any form of dead axle. Some of these advantages can be attained without front-wheel drive, but they are logical and useful when combined with such a drive.

Pitching is said to be almost eliminated in some front-wheel-drive cars. Doubtless this is more a matter of springing and weight distribution than of drive, yet a front-drive design probably makes it easier to attain this advantage. A factor tending to improve riding-quality, as compared with a car having the Hotchkiss rear-axle drive, is that the rear springs are used for suspension only and are relieved of driving and torsional stresses.

Nearly all engineers experienced with front-drive cars comment upon the increased safety, (4), due to the decreased tendency to skid on turns. This has led to the extensive use of such drives on racing cars. Very likely this is due in part to the fact that the driving force is applied always in the direction in which the front wheels are headed, while with rear drive this force always is parallel to the axis of the car and therefore is at an angle to the

Advantages

(1) Relatively unencumbered space for a body of almost any desired design, floor height and dimensions
(2) Elimination of a bulky and complicated rear axle
(3) Possibility of improved riding-qualities, including a lessened pitching tendency
(4) Increased safety due to less skidding tendency and to ability to take turns at higher speed
(5) Driving force always applied to the wheels in the direction of their motion
(6) Elimination of a long propeller-shaft, and substitution of shafts having lower speed and less tendency to vibrate
(7) Possibility of improved traction under certain conditions
(8) Possibility of greater quietness and freedom from body rumble
(9) Ability to provide front-wheel braking without carrying brake-drums and operating mechanism on wheels or axles
(10) Lower upkeep-costs due to greater accessibility and better lubrication
(11) A less expensive rear-axle and a simplified frame-construction
(12) Freedom from shimmy tendencies
(13) A possible decrease in tire wear due to lessened skidding tendency
(14) Decrease in the total weight of the vehicle
(15) Decreased side-sway
(16) Decreased thrust on front-wheel bearings
(17) Front axle and springs can be relieved of all braking torque
(18) All springs can be relieved of driving-torque reaction

planes of the front wheels when they are cramped. At such times there is a component parallel to the axis of the front wheels that tends to cause them to skid. This component increases rapidly as the turning angle increases.

The decreased tendency of front-drive vehicles to skid, and the fact that the driving force turns as the wheel is cramped in steering, make it possible to negotiate curves at higher speeds and thus to add to the safety of driving. To the extent that a front drive lowers the center of gravity of a vehicle it adds again to the safety factor. This is an indirect result due to the lower body-platform rather than to the front drive itself.

The front drive always applies the driving force in the plane of the front wheels, (5), even when they are cramped, and hence in the direction of desired motion. This is an obvious advantage and probably contributes some net increase in mechanical efficiency when rounding a turn besides reducing the skidding tendency; but the advantage may be offset in part by an increase in the mechanical losses in universal-joints that transmit the drive at an angle. Probably neither item is of very great practical moment.

It is an unquestioned advantage, (5), to eliminate the long high-speed propeller-shaft needed with a rear-wheel drive, especially in vehicles having a long wheelbase, for long shafts have tendencies to whipping and periodic vibration. It is also difficult to assure good lubrication of high-speed universal-joints. Long motorcoach and truck chassis often need one or more propeller-shaft bearings for steadying purposes, and these add somewhat to first cost as well as to upkeep expense.

Advocates of front drives contend that the alternative, that is, two short universal-jointed shafts having lower speed and higher torque, is preferable, since any unbalance in the short low-speed shaft is less apt to cause vibration and noise. Although it is easier to retain lubricant in low-speed universal-joints, the front-drive generally has from two to four times as many universals as the rear drive; therefore it is questionable whether the lubrication problem is simplified.

Disadvantages

(1) Decreased traction under some conditions, notably in hill climbing and when accelerating

(2) Possibility of greater injury to the driving mechanism in the event of collision

(3) Difficulty of obtaining satisfactory weight-distribution, especially in trucks and motorcoaches

(4) Increased over-all length, or an increased wheelbase for the same length of body

(5) Increased complication in the driving mechanism

(6) Decreased space for the radiator

(7) Increased expense of the front axle, or its equivalent, and the driving mechanism

(8) Insufficient road-clearance in front, considering the present small-diameter wheels

(9) Difficulty of getting a quiet drive, especially with a bevel drive mounted on the frame

(10) Possible slight decrease in mechanical efficiency

(11) Harder steering due to increased load on the front axle and the steering pivots

(12) Difficulty of obtaining an adequate steering-angle

Improved Traction Under Certain Conditions

While there seem to be certain conditions under which front-drive vehicles give better traction, (7), I have been unable to see any ground for the sweeping claims made for them in this regard. The mere fact that the vehicle is pulled instead of being pushed is of no moment in itself so long as the propelling force is in the same direction.

In his article on front wheel drives[2], P. M. Heldt points out that one condition in which front-drive vehicles have a tractive advantage is when the front wheels sink into a mud hole. He says that "the resultant of the weight on them and of the forward push of rear driving-wheels, tends to force them deeper and deeper into the mud. With front drive, on the other hand, the propelling force, which acts tangentially at the rim of the driving wheels, tends to lift them out of the hole." This assumes that the front wheels are lower than the rear wheels, so that the propelling force, which is approximately parallel to lines joining front and rear hub-centers, has a downward component. If, however, we consider a condition similar in other respects but with the rear wheels in the mud hole and lower than the front wheels, the rear drive has the same advantage as the front drive in the other case. The two constructions therefore seem to be of equal merit in these two parallel conditions.

The front drive does appear to have an advantage, however, in plowing through a level stretch of fairly soft snow or mud, assuming equal weight on the driving wheels in both cases. Here a component exists that tends to lift the front wheels over the mud or snow while the rear wheels follow in their tracks. There are said to be cases of this kind in which front-drive motorcoaches have been able to operate readily where rear-drive motorcoaches stalled. Other similar conditions doubtless exist in which driven front-wheels will "lift" themselves over obstacles when the rear drive might not be able to force the front wheels over, but the practical importance of these conditions probably is less than those in which the rear drive has an advantage, notably in hill climbing.

T. J. Lítle, Jr., says, regarding the possibility of decreasing noise, (8):

> If we isolate the powerplant from the body, as we do in the case of a front-wheel drive, we have a much quieter riding vehicle; for automobile bodies of today are efficient resonators and, when we provide a direct metallic path from the engine, which is the primary source of vibration, and telegraph the disturbance under the entire body, it is often next to impossible with rear drive to make such bodies quiet unless we resort to a soft non-resonant covering such as fabric.

Another engineer mentions the difficulty of obtaining

[2] See *Automotive Industries*, June 4, 1927, p. 831.

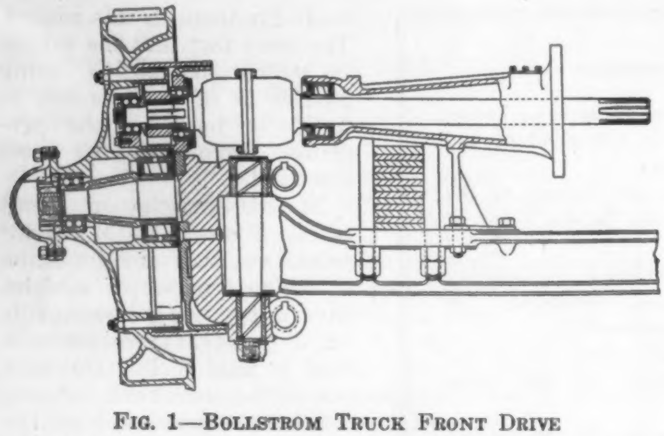


FIG. 1—BOLLSTROM TRUCK FRONT DRIVE

This Drive Is Similar to Some Rear Drives Except for the Steering-Knuckles and the Universal-Joints. The Entire Axle-Housing and Internal-Gear Drive Constitute Unsprung Weight, but They Seem To Provide a Substantial Construction for Truck Applications

quietness when the spiral-bevel drive is mounted on the chassis frame, or in a unit with the powerplant, as it is with most front drives. This leads me to question whether a front drive is likely to be quieter in practice than a rear drive, especially when the latter is insulated from the body to a certain extent by the springs. I should expect the greater noise with the uninsulated front drive unless a worm gear is employed, as the frame might easily transmit the vibration and noise more positively to the body than would the rear springs. If, however, it is a question of transmitting *sound* waves through the *air*, the front drive well may be the more quiet, and it is likely to be so with worm drive unless the design is such that the engine must be placed farther aft.

FRONT BRAKING-MECHANISM ON THE CHASSIS

Brakes on the front wheels have at least three disadvantages that can be overcome easily on a car having front-wheel drive: (*a*) they add to the unsprung weight on the wheel, (*b*) they require an actuating mechanism

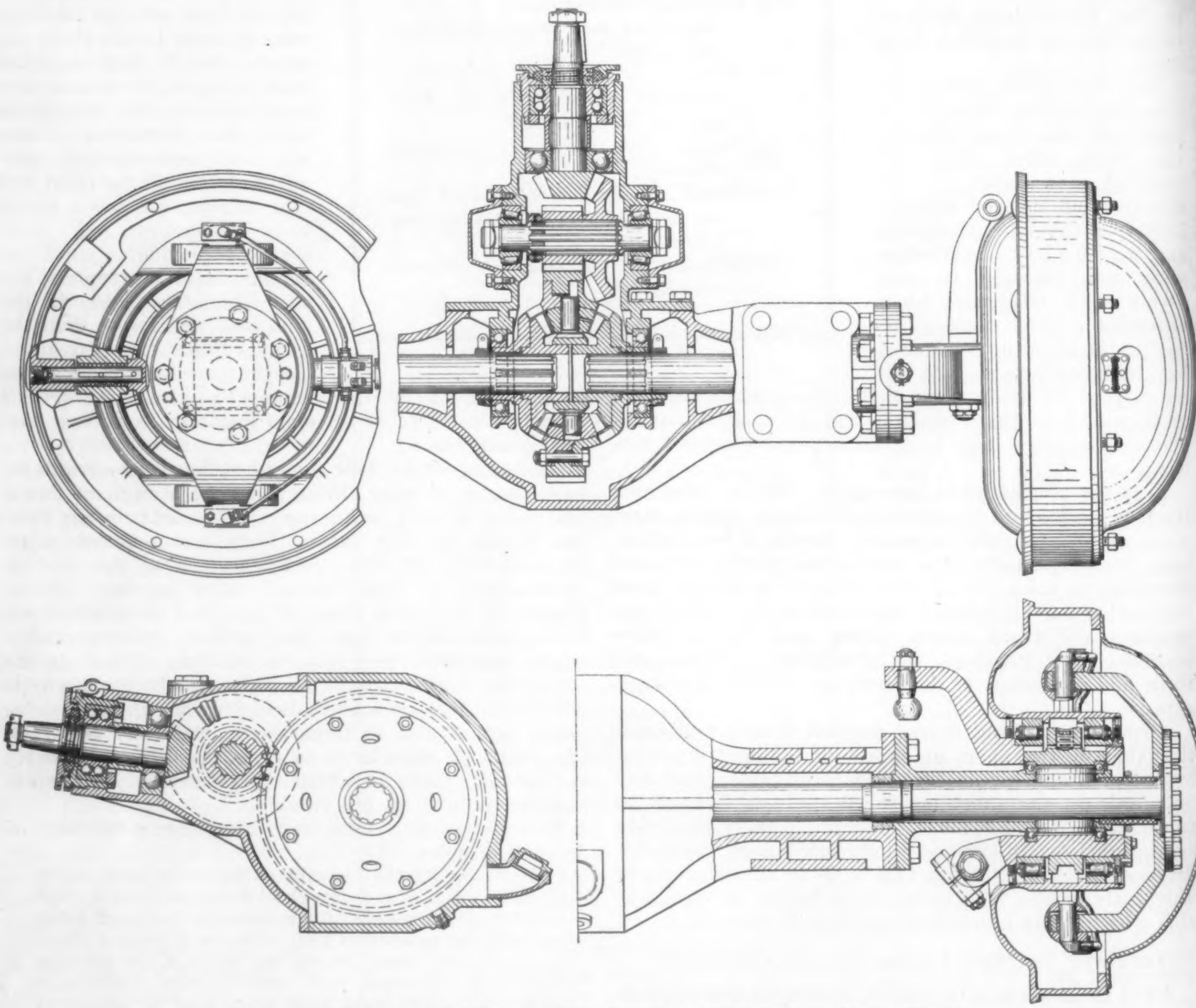


FIG. 2—FRONT AXLE USED IN THE COLEMAN FOUR-WHEEL-DRIVE TRUCK

The Novel Feature of This Design Is the Universal-Joint Inside the Wheel. The Wide Spread of the Yoke Bearings Reduces the Bearing Pressures at These Points. The Axes of the Yoke Bearings and the Steering-Pivot Are in the Same Plane

that is not affected by cramping the wheels or by the displacement of the axle when spring action takes place, and (*c*) they impose braking stresses on axle and springs. With front-wheel drives these disadvantages are eliminated by the simple expedient of mounting the brakes on the chassis frame, (9). They can be placed at either side of the differential, as in the Miller and the Marmon designs, or on the propeller-shaft either in front of the differential, as in the Rumpler design, or aft of the differential. When placed on the propeller-shaft, the differential automatically equalizes the braking stresses between the two front wheels.

The chassis mounting of the mechanism simplifies braking connections and, by relieving the axle and springs of braking torque-reactions, permits the use of lighter parts and certain forms of construction, such as in the Alvis design, which otherwise would not be feasible. Chassis-mounted brakes are very easily enclosed and are less likely to be affected by dirt, water and ice than are brakes mounted on the wheels. Brake cooling also is more effective than with propeller-shaft brakes on rear-drive vehicles.

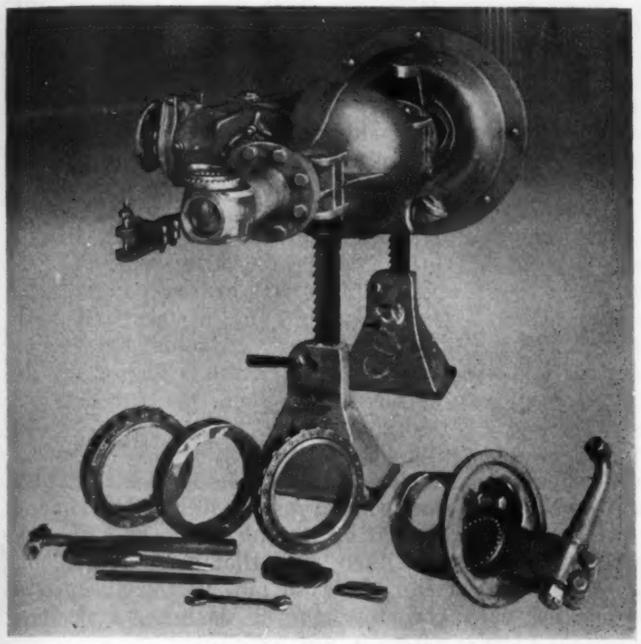


FIG. 3—COLEMAN FRONT-AXLE PARTS

DECREASED UPKEEP COSTS

As with rear-drive vehicles, servicing is greatly simplified and rendered less expensive if the design is such as to permit easy access to parts needing attention, (10). Such accessibility is obtained easily with front-wheel drives when the designer gives it due consideration. The clutch, the gearset and the differential, being in front of the engine, are easily reached. If the design is well worked out, all parts likely to need relatively frequent attention are arranged for quick and easy detachment. As a general rule, the engine need not be any less accessible than in conventional types of rear-drive car.

It is also easy to arrange the entire powerplant and front axle in a unit that can be detached easily and quickly from the chassis for shop servicing while a spare unit is substituted. This has been done in the Healey-Aeromarine motorcoach, in which the entire power unit and drive is detachable after removing two bolts. This is in great contrast with the trouble usually involved in taking a rear axle and powerplant out of the ordinary motorcoach-chassis, and the greater accessibility of the Healey-Aeromarine design is evident.

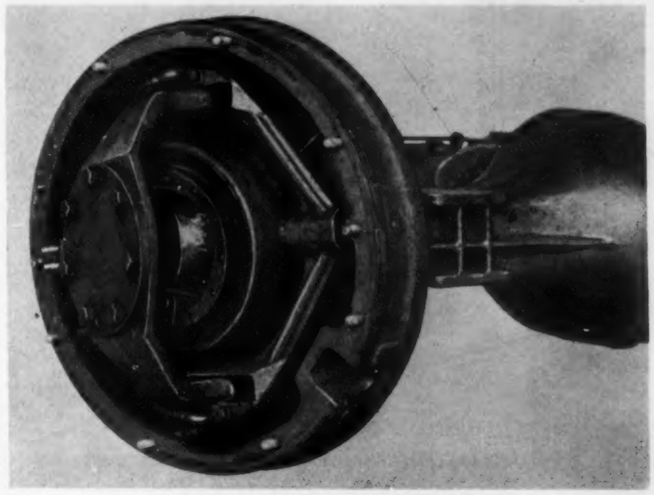


FIG. 4—COLEMAN UNIVERSAL-JOINT
The Very Large Diameter of the Universal-Joints Is Evident. This Is an Example of Class-1 Design in Which a More or Less Conventional Rear-Axle Type Has Been Adapted To Perform the Steering as Well as Driving Functions. The Complete and Rather Heavy Assembly Is Unsprung

The close grouping of all the important mechanical units of a passenger-car, motorcoach or motor-truck, can easily lead to inaccessibility of certain parts; but, if the designer displays equal skill in both cases, the front drive seems likely to be easier to service. The close combination should make it easy to oil all important parts from the main oil-supply of the engine, thus reducing the need for that class of service which poor lubrication so often makes necessary.

It will hardly be denied that a less expensive rear axle, (11), is possible with front-wheel drive, but the important question is whether the front and the rear axles considered together will cost less. No categorical answer is possible, but it is probable that the total cost will be lower in certain designs, for the rear axle can be either a simple dead type or be discarded entirely in favor of pivoted arms of moderate cost, such as are used in the Rumpler and Alvis designs. The front axle, or the load-carrying part of it, also can give place to transverse springs as in the Itala and Alvis designs, or to distance-arms such as are used in the Healey-Aeromarine motorcoach. In these cases some other items such as knuckle forgings and extra universal-joints must be considered also; therefore the total cost may be either greater or less than that of conventional construction.

Frames can be made more cheaply for front-drive vehicles in certain designs, partly because side-rails need have no kick-up, front or rear. In one design the ordinary frame has been eliminated and the body constructed in such a way as to support its own weight as well as the passenger load. This particular construction may or may not decrease cost, but the case in favor of decreased frame-cost has some plausible arguments in its favor.

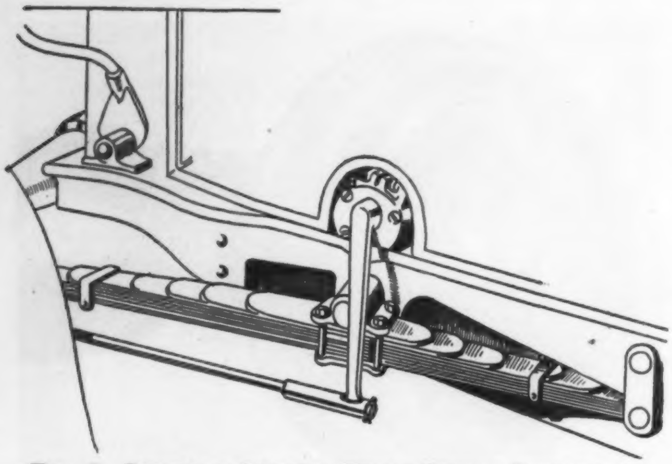


FIG. 5—BUCCIALI CHASSIS FRONT-SPRING SUSPENSION

FREEDOM FROM SHIMMY TENDENCIES

In his paper on Independently Sprung Front Wheels as a Remedy for Shimmy[3], M. de Lavaud makes this interesting statement:

> One usually dilates upon the remarkable steadiness and roadability of cars fitted with front drive. One should note that front-wheel drive is, in principle, associated with independent front wheels. It is precisely that independence, and not the fact that the drive is from the front, which produces those unquestionable advantages that have been verified. My opinion is that, apart from a few practical and secondary advantages, the front-wheel drive does not, in itself, produce any real technical benefit.

I agree that the individual springing of front wheels, for reasons which M. de Lavaud points out, undoubtedly is to be credited with the elimination of shimmy troubles in front-drive cars; but the very fact that, as M. de Lavaud says, front-wheel drives usually are associated with independent front-wheel springing is at least an indication that such drives lend themselves well to this type of construction. Hence it seems proper to include freedom from shimmying among the advantages of such front-drive *design*, although this benefit is not due to the drive as such. It is in order to say, however, that it is not essential to turn to the front drive to realize the non-shimmying advantage of independently sprung front wheels, and that front-wheel drives in which the wheels are not independently sprung probably will not be free from shimmying.

[3] See THE JOURNAL, June, 1928, p. 623.

POSSIBLE DECREASE IN TIRE WEAR

With a drive always parallel to the direction of motion, front-tire wear should be at the minimum, (13). But the front-tire wear doubtless will increase because the tires, being driven, are abraded on account of spinning when traction is poor or when it is reduced to zero and suddenly increases to normal. This happens when a tire bounces off of the road surface, is accelerated by the drive through the differential, and again makes contact with the road. In these respects driving front tires becomes similar to driving rear tires, but an advantage may exist due to lessened unsprung-weight. Whatever is lost in greater front-tire wear due to front driving-forces should be gained in lessened rear-tire wear, with a probable net gain in favor of the front drive, all four tires being considered in both cases. This is said to be in line with actual experience, but whether the observed conditions can be considered as being strictly comparable may be questionable.

DECREASE IN TOTAL WEIGHT OF VEHICLE

When springs or distance-members are made to take the place of axles, the saving in total weight, (14), as compared to a similar vehicle with ordinary dead axles, is considerable. On the other hand, at least a part of this weight can be saved by using a somewhat similar construction and retaining rear drive. Therefore, the gain cannot be credited to the fact that the drive is to the front. If we consider certain types of front-wheel-drive car as a whole, however, it is fair to say that the weight well can be made less than that of a comparable vehicle of conventional design. Consequently, we are justified in listing weight saving as a possible advantage. It seems likely also that some frame and some body weight can be saved but, in the absence of comparable data covering specific designs, a positive statement to that effect is not warranted.

DECREASED SIDE-SWAY

Published reports of unofficial trials of certain front-wheel-drive cars refer to comparative freedom from side-sway (15), in rounding turns. This, I infer, is due more to springing, possibly to individual wheel springing, than to anything inherent in the front-wheel drive itself. For this reason I merely list decreased side-sway as a possible advantage of certain designs

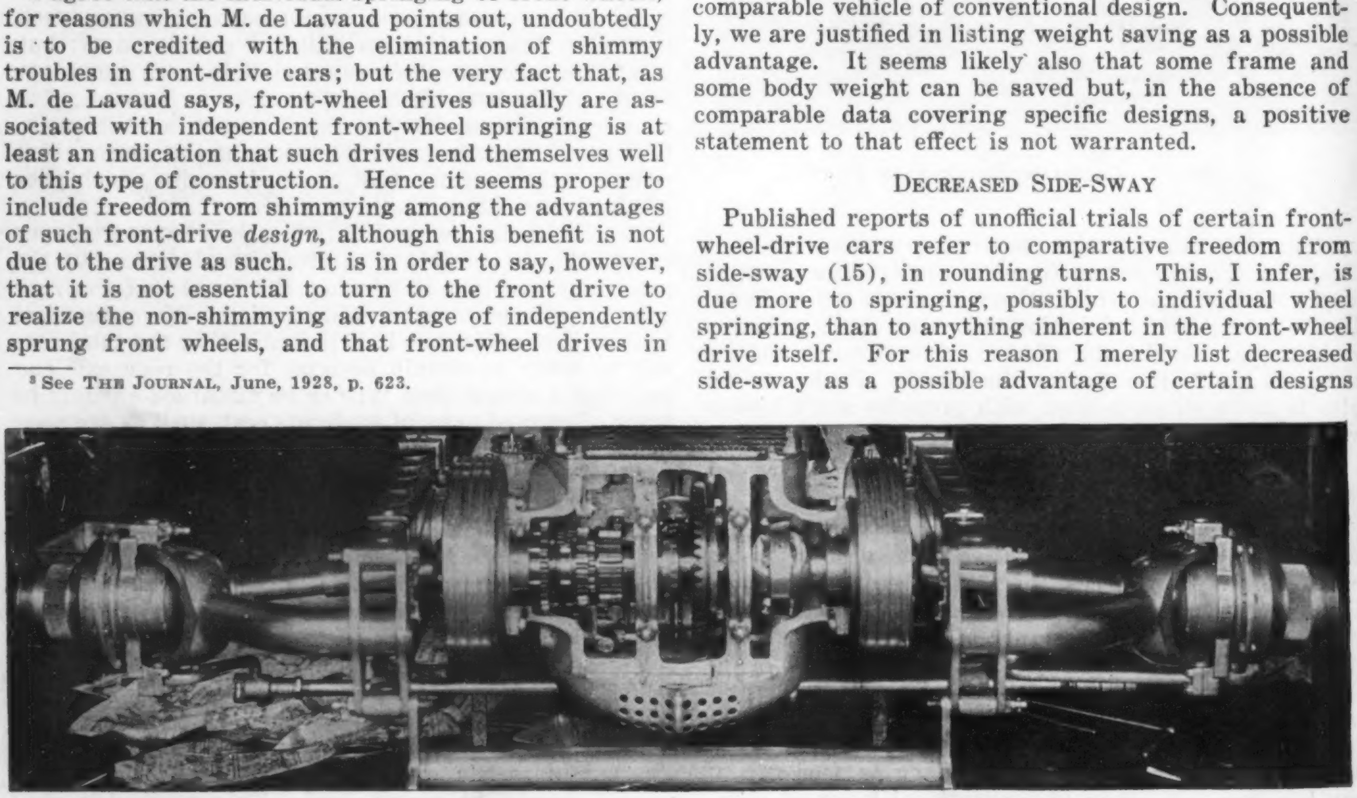


FIG. 6—FRONT VIEW OF MILLER FRONT AXLE

Part of the Bow-Shaped Dead-Axle and the Differential Cover Are Removed To Show the Arrangement of the Gearing. Some of These Axles Have Two-Speed and Some Have Three-Speed Gearsets

using front drive, although I am inclined to believe a similar claim might apply just as well to certain unconventional rear-wheel-drive designs also.

Decreased Thrust on Front-Wheel Bearings

W. H. Douglas, who has had, I believe, as long an experience with front-drive vehicles as any American engineer and is largely responsible for the Healey-Aeromarine design, points out that the universal-joint and the steering-system used in this motorcoach gives a maximum steering-angle of 53 deg. He adds that the allowable steering angle of rear-driven vehicles is limited by the side-thrust on the front wheels. It is evident that rear drives do impose heavy side-thrust on front-wheel bearings, that such thrusts increase materially as the steering angle is increased, and that the thrust is far less, (16), with front-wheel drive. It may well follow that a front-drive motorcoach can use a larger steering-angle than one with rear drive and not be subject to excessive thrust on front wheels and their bearings. In any case it hardly will be denied that the Healey-Aeromarine motorcoach has an exceptionally large steering-angle and a correspondingly small turning-radius for so long a vehicle.

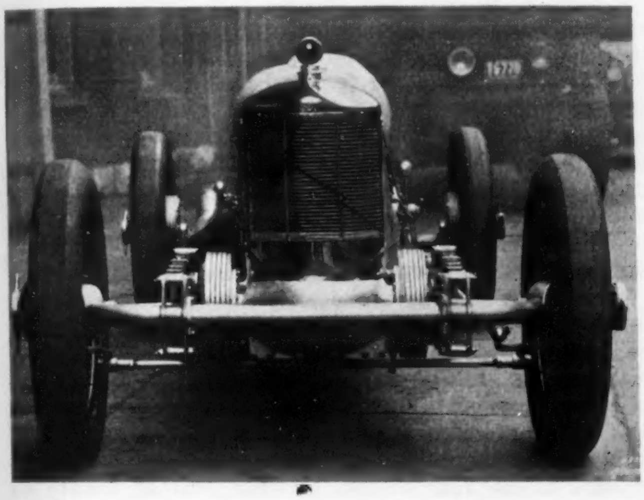


Fig. 7—Marmon Racing Car with a Ruckstell Axle

This Design Is Typical of the Designs in Class 2 in Which the Steering-Knuckles Are Joined and Positioned by a Dead Axle, but in Which the Differential, the Brakes and the Gearset Are Sprung, Being Mounted in a Unit with the Engine

Front Springs and Axle Relieved of Braking Torque

Any construction which relieves the front springs and axle from the torque reaction due to braking, (17), and still provides braking on front wheels, offers a distinct advantage; and this is the case with most front-drive designs. Brakes can be carried at the inner end of each driveshaft, or on the propeller-shaft, preferably forward of the differential where the cooling effect is good. Such a construction also makes for simple brake-controls and a reduction in unsprung weight.

Summary of Advantages

Even though numerous reservations attach to this rather formidable list of front-wheel-drive advantages, the case for such drives has strong arguments in its favor. We have yet to examine the disadvantages.

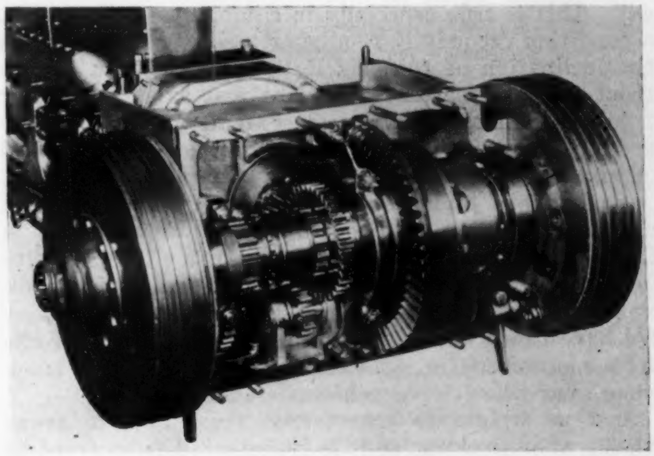


Fig. 8—Ruckstell Gearset and Differential Used on the Marmon Racing Car

It Should Be Noted That the Gearset Is Placed Beside the Differential. With This Arrangement There Need Be No Material Increase in Over-All Length of the Powerplant, and the Engine Need Be Placed Little, if Any, Farther Aft Than with Rear-Wheel Drive

Discussion of Disadvantages

Since maximum tractive-effort is a direct function of the weight on the driving wheels, (1), a decrease in that weight reduces tractive effort proportionately. This is of small moment so long as the minimum is enough to propel the vehicle without undue slippage, but below this minimum the vehicle stalls. In a passenger-car, with all the weight of the engine and driving mechanism forward and the weight of passengers relatively small in proportion to the total weight on the front axle, the chance of insufficient traction is not very great; but, in a motorcoach or motor-truck designed for heavy loads on the rear axle, the case is wholly differ-

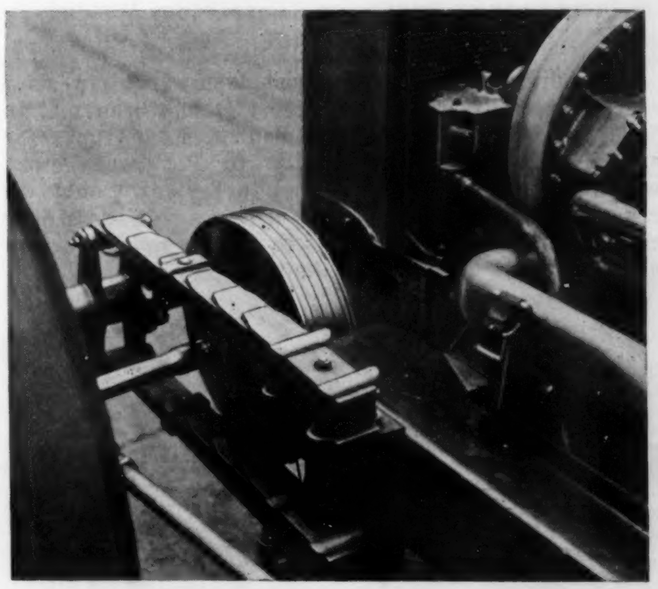


Fig. 9—Spring Suspension on the Marmon Racing Car

The View Shows One of the Two Pairs of Quarter-Elliptic Springs Which Support the Front of the Chassis. The Position of the Brake-Drum Should Be Noted; It Is Accessible and Is in Good Position To Assure Proper Cooling, Yet It Constitutes Part of the Sprung Weight

ent. This is true especially in climbing a heavy grade, a condition frequently requiring maximum traction, as the inclination of the vehicle lightens the load on the front axle and increases it on the rear axle. A greater front overhang helps to some extent, but many cases are on record in which front-drive trucks have stalled on hills, especially when the footing of the road was poor.

Basing his remarks on some 70 front-wheel-drive motorcoaches that have operated millions of miles in Chicago, G. A. Green mentions the difficulty of obtaining a satisfactory weight-distribution to provide sufficient front-wheel traction as the first disadvantage. We have heard of one case, however, in which a front-drive motorcoach is reported to have operated in snow when rear-wheel-drive vehicles stalled.

Just as weight is transferred from rear to front wheels when braking, so it is transferred from front to rear wheels when accelerating. This also militates against the front-wheel-drive vehicle under a condition in which the need for traction is great. It is therefore apparent that decreased traction does limit the usefulness of some classes of front-drive vehicle, though it probably is not a serious disadvantage in passenger-cars. In some cases, in fact, the traction actually is greater than with rear drive.

Possibility of Greater Injury in Collision

With a differential and live axle "sticking out in front", these units are perhaps more likely to be damaged seriously in a collision, (2), than in a vehicle of conventional construction. This does not apply to all front-wheel-drive designs, but is properly urged against some and has led the makers of the Tracta car to provide a substantial bumper as an aid to selling their product. Radiators and engines of rear-drive vehicles often are injured in collision, but the damage to a front-wheel drive might easily prove more serious under similar conditions.

Difficulty of Obtaining Satisfactory Weight-Distribution

This difficulty, (3), is almost insuperable in some cases, especially in motor-trucks. It has been met in some motorcoach designs and also in motor-trucks for special purposes, but inability to get satisfactory weight-distribution has resulted in serious trouble in other cases. In passenger-cars it seems to be less difficult to distribute weight so as to give as much traction as is required under all ordinary conditions.

Increased Over-all Length

The disadvantage, (4), that front-wheel drive requires a vehicle of longer wheelbase than is needed for a similar body on a rear-drive chassis, has been cited by J. G. Vincent and other engineers. No doubt this is true if the gearset and differential are placed in front of the engine and the engine is moved back in the chassis. Strangely enough, however, a similar disadvantage in over-all length does not preclude the use of an eight-in-line engine when the sales possibilities of a car with such an engine are considered good enough! Although there are difficulties it does not seem impossible to design a front-wheel-drive car which, for a given body length, would have very little if any increase of over-all length. Suppose, for example, that we take a conventional chassis and merely turn the engine around, without moving it forward. We can then bolt up a differential housing which would come but little if any farther forward than the present radiator. The center line of the front wheels then would come about at the radiator, where it is now. The gearset could then be placed forward of the radiator, in a space now seldom used to advantage, or be placed beside the differential as in the Marmon and the Miller designs. With such an arrangement there would be little increase in over-all length or in wheelbase.

It is impossible to make exact comparisons without using scale layouts, but I venture to predict that an engineer who set out to design a front-wheel-drive car with a given length of body and engine, and who made an effort to keep the over-all length within that for a similar car of conventional design, would find a way of doing it satisfactorily. Despite these alternatives, it appears to be fair to list greater over-all length or increased wheelbase as one of the disadvantages of a front-drive vehicle, for there are admitted difficulties in developing a design without such an increase.

Increased Complication of Driving Mechanism

The greater complication of a front-wheel drive, (5), is among the disadvantages invariably mentioned by those who do not favor front-drive design. Here, as in certain other cases, the argument undoubtedly is sound for certain types of construction, but it is open to question for other types. If we consider designs such as those falling in Class 1, there probably is a disadvantage in the front drive on the score of complication. What we do in effect is to interchange the front and rear axle, making the latter a one-piece forging. The front axle

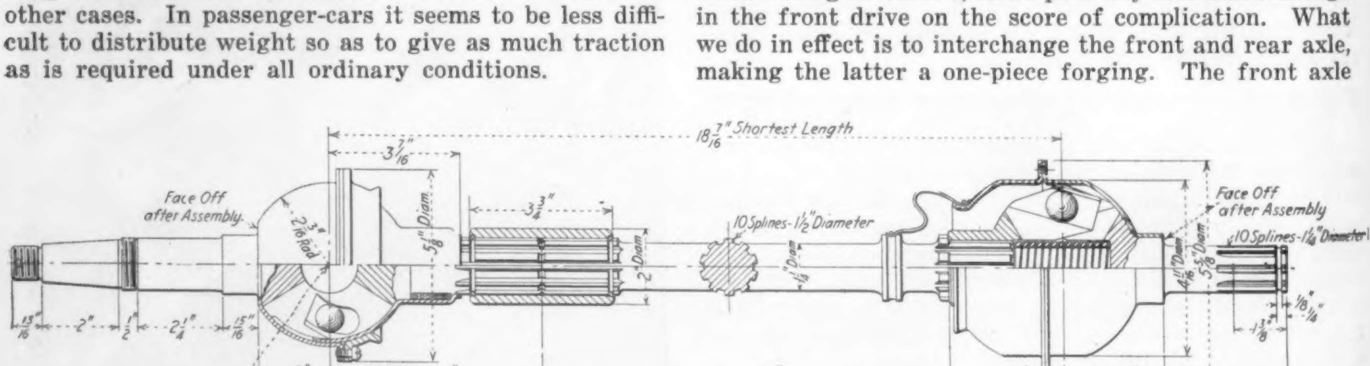


Fig. 10—Weiss Universal-Joint and Shaft Construction

This Drive Is Similar to That Used in the Marmon Racing Car and in Experimental Front-Drive Cars Now Undergoing Test. The Universal-Joints Are Designed To Give Uniform Angular Motion. The Inner Universal-Joint Permits 1 In. of Axial Motion on a Rolling Contact; Hence, No Sliding Spline Is Required

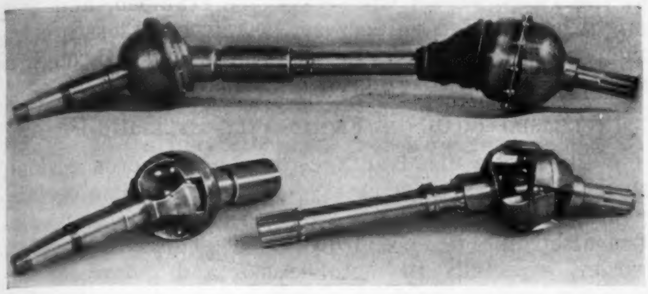


Fig. 11—Weiss Front-Drive Universal-Joints and Shaft Assembly

The Ball Raceways of the Inner Joint Are Straight; Those in the Outer Joint Are Curved and Permit Angular Deflections in Excess of 30 Deg.

is altered to provide steering-knuckles and a universal-joint drive to short stub-axles. In this case the stub axles and at least two of the four universal-joints represent extra parts, and the knuckle forgings become larger and more complicated. If, on the other hand, we compare conventional construction with designs such as those in Classes 2 and 3, it is a question whether the complication actually is increased.

To make the comparison fair, it is necessary to compare not only the two front-axles but the mechanism of the vehicle as a whole. Without going into too much detail we have in both cases a propeller-shaft, but with front-wheel drive it usually is merely an extension of the tail shaft of the transmission and requires no universal-joint. We therefore save either one or two universal-joints in respect to this item and also avoid the use of a torque-tube or a torque-arm which is used in some cases. As to the rear axle, we already have pointed out that this can be a very simple structure, either straight or cranked, or it can be eliminated in favor of wheels fixed at the end of pivoted radius-arms. In either case there will be a considerable saving in complication as compared with the present conventional type of rear axle with its expensive hollow housing, two live-axles and the like.

Considering the front axle, we find that this can be a simple tube bowed forward, such as is used on the Marmon and the Miller racing cars, or a somewhat more complicated tubular structure such as is employed by Tracta. But the carrying member proper need not be more complicated than the present Elliott or the reversed Elliott front-axle center. Even this can be done away with by making springs or distance-members the supporting part, as is done in several designs described herein. In any case we require knuckle forgings of some form; and these probably will be somewhat more expensive, if not more complicated, in the front-wheel-drive design. The bevel drive-gear, bevel pinion and differential will be approximately the same as in present conventional construction, but the housing probably will be somewhat less expensive since it can be cast rather than forged.

We now require two drive-shafts similar to the live shafts used in a rear axle, except that four universal-joints are needed, one at each end of each shaft, this being two or three more than are required for the conventional rear drive. These universal-joints must be designed to carry greater torque than in a rear-drive vehicle, but do not run at such high speed. The short stub-axle required in each wheel is a relatively simple part and probably would be no more expensive than the ordinary front-axle spindle.

If we now strike a balance, we find that the only important extra parts required for the front drive are two or three extra universal-joints, while on the other side of the ledger we save a heavy rear-axle housing, which is an expensive forging, a torque-tube or a torque-arm in some cases, and a front-axle center in others. There also may be some other relatively minor credits, depending upon the specific type of design employed, but it seems possible in certain cases actually to reduce complication by using a front-wheel drive.

Decreased Space for the Radiator

Whether there is actually less room for a radiator in the front-wheel-drive design, (6), depends again upon the type of construction employed. In certain cases there doubtless will be less room, but in no case does it seem impossible to provide a radiator of adequate size without great difficulty.

Front Axle and Driving Mechanism Costs

Here, as in other cases, we must deal largely in generalities since detailed and specific data for comparison are not at hand. If we grant, however, that a front drive is more complicated than a rear drive, as appears to be the case in certain instances, then the expense doubtless will be greater, (7). If, on the other hand, we confine ourselves to certain other types of front-wheel drive, there appears to be at least a possibility of less complication and less expense.

Insufficient Road-Clearance with Small Wheels

While insufficient road-clearance, (8), is doubtless very real in some front-wheel-drive designs, such as in the Marmon racing car in which there is a road clearance of only 1 in. when the tires are completely deflated, presumably it can be overcome readily in other types of design. In the Itala and the Alvis designs there is practically nothing below the transverse springs except the drag-links, and these can be placed higher

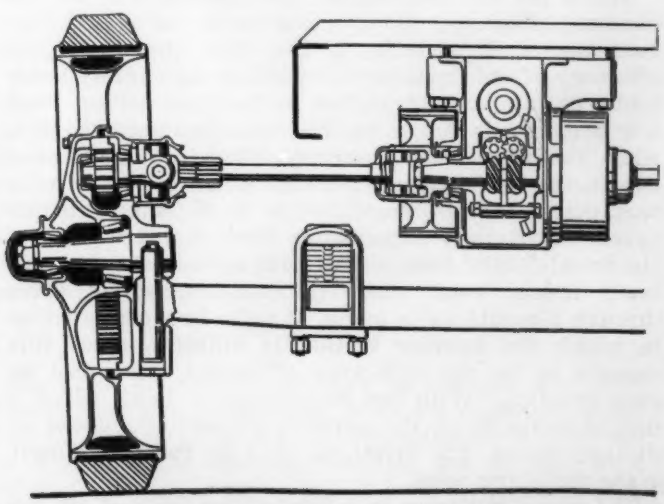


Fig. 12—Front Axle of Walter Four-Wheel-Drive Truck

In This Design the Dead-Axle Center Joining and Positioning the Steering-Knuckle Is Placed below the Differential, Which Is Mounted on the Frame. The Second Reduction Is by Internal Gear and Pinion within the Wheel; Hence, the Torque on the Universal-Joints Is Less Than in Single-Reduction Designs Transmitting the Same Power

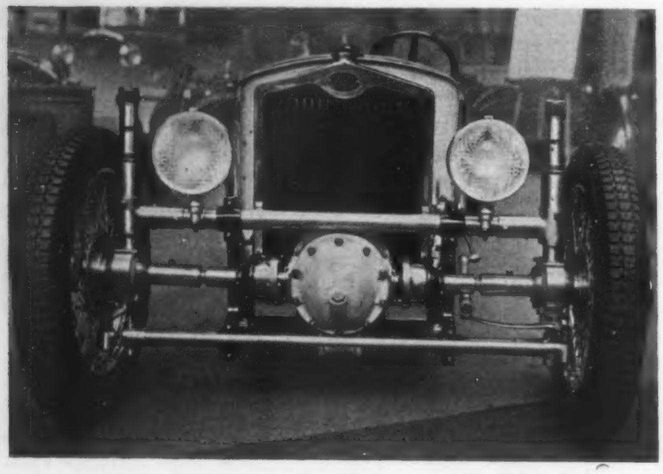


FIG. 13—THE TRACTA, A RECENT FRENCH DESIGN
Unlike the Other Designs in Class 2, This Has a Dead Axle That Is Sprung. The Wheels and Parts Immediately Adjacent to or Inside Them Constitute the Whole Unsprung Weight. The Springs Are of Helical Type and Are Located Inside Cylindrical Steering-Knuckle-Pivot Guides

by adopting an expedient similar to that used in the Healey-Aeromarine design.

DIFFICULTY OF GETTING A QUIET DRIVE

A difference of opinion exists as to whether a front drive will be more quiet than a rear drive, (9). One prominent engineer contends that it is difficult to make a bevel gear quiet enough when it is in a housing on the frame, as would be the case with the ordinary front-wheel drive. Another of equal prominence takes the view that when the drive is carried back under the body in conventional fashion there is likely to be more noise than if a front drive is employed. I do not know which of these two views is correct, but I venture the opinion that it will not be a difficult problem to provide a quiet front-wheel drive of some type, once engineers apply themselves to this task. No doubt a worm drive would be sufficiently quiet.

While the disadvantage of possible decrease in mechanical efficiency, (10), seems to be of very minor consequence, it probably is true that the mechanical efficiency of the front drive itself may be slightly lower under certain conditions than is the rear drive. Such a contention is based on the tacit assumption that, when the wheels are cramped, there is a mechanical loss in the universal-joints which would not occur with rear drives. Tests mentioned by C. W. Spicer in his paper on Action, Application and Construction of Universal-Joints[4] have shown that such losses are very small indeed even when the universal-joints drive through a considerable angle. I refer to a construction in which the angular motion is uniform, since this appears to be the only type of layout sanctioned as good practice. With the Weiss type of joint, which I shall describe later, the contacts are rolling instead of sliding; hence, the frictional loss is reduced almost to the vanishing point.

The propelling force in a front-wheel drive is always in the direction of the plane of motion of the wheels, but this is not true on turns with the rear-wheel drive. Consequently, there is at least an incipient slippage at the front wheels when they are cramped, and this might be expected to increase the frictional losses more than they would be increased by the drive through a universal-joint operating at a considerable angle.

INCREASED LOAD ON FRONT-AXLE STEERING-PIVOT

While it is a disadvantage to have an increased load on the front-axle steering-pivot, (11), there is a certain compensation in having a smaller load on the rear axle. The disadvantage is that it makes steering somewhat harder, especially in motor-trucks and motorcoaches. It is not certain, without specific comparison, that the load on the front axle would be increased materially in all passenger-car designs, especially if the engine is placed farther aft and a lighter front axle or its equivalent is used. On passenger-cars, there probably would be only a small difference in any case, and it can be offset by using a trifle greater reduction in the steering-gear.

DIFFICULTY OF OBTAINING AN ADEQUATE STEERING-ANGLE

The maximum steering-angle, (12), in some front-wheel drives is limited by the allowable angularity under which the universal-joints can operate satisfactorily. If this angle is less than is readily possible with rear-wheel drive it is a real disadvantage; but we have noted already that a larger angle than is common with rear-drive vehicles can be and is employed with satisfaction in the Healey-Aeromarine motorcoach, in which the maximum steering-angle is 53 deg. Apparently, then, the difficulty in getting an adequate steering-angle applies only to designs in which the variation in angular velocity would become excessive if the steering angle were increased.

SUMMARY OF DISADVANTAGES

A total of 12 disadvantages credited to the front-wheel drive may seem rather formidable; but, as noted, most of the disadvantages are overcome readily by simple modifications in design. Those which remain

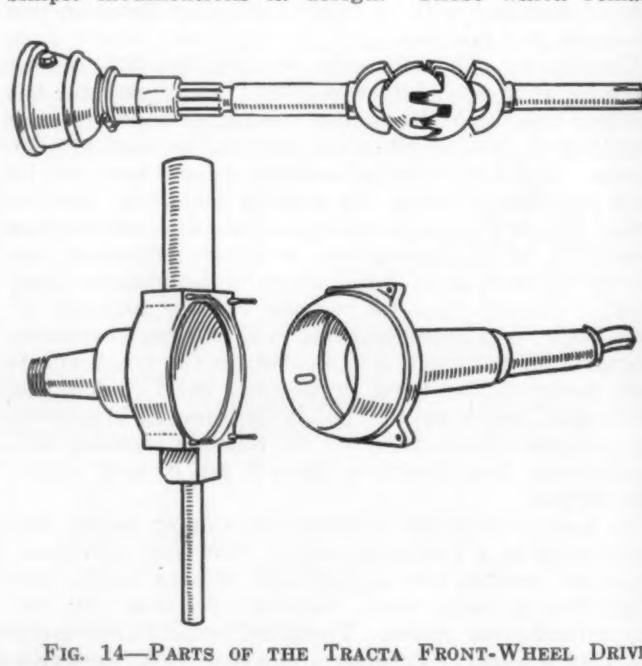


FIG. 14—PARTS OF THE TRACTA FRONT-WHEEL DRIVE
The Universal-Joints Are Said To Give Uniform Angular Velocity

[4] See THE JOURNAL, December, 1926, p. 627.

are in no way serious and probably are no greater than those which can be cited against most important mechanical features of the common automobile of today.

Advantages Probably Outweigh Disadvantages

Before preparing this paper I was inclined to think that the disadvantages of the front-wheel drive outweigh the advantages, when compared with the conventional rear-drive design, but the more I study front-wheel-drive design, the more inclined have I become to believe that the reverse is true. The number of advantages listed is greater than the number of disadvantages, and I think the advantages are also rather more important. This is largely a matter of opinion, and I have no quarrel with those who hold the contrary view. My opinion has been formulated entirely from a paper study of existing design, as I have had no actual experience with front-wheel drives. With one or two notable exceptions, however, these conclusions seem to coincide closely with those expressed by several other engineers who have made some study of front-wheel design, and most of whom have had practical experience with such designs.

Front-Wheel-Drive Types Compared

Having studied the pros and cons of front-wheel drive design in general, a brief discussion of the various types concerning which I have been able to collect more or less information perhaps will be helpful to those who are not already familiar with the present status of the subject. A large portion of the particulars given herein necessarily has been taken from published descriptions, but I believe that several of the designs presented have not been described in American publications and that some have not hitherto been published. All these designs will be considered under Classes 1 to 3, as already stated.

Specific Examples of Class 1

In the Bollstrom truck, shown in Fig. 1, the front axle resembles one form of rear axle except that steering-knuckles with universal driveshafts are provided. In this case there is an internal-gear reduction inside the wheel. This and the central housing with its differential and primary reduction-gearing add to the unsprung weight, but they present a rugged type of construction apparently well suited to truck applications[5].

Although the Coleman truck is a four-wheel-drive vehicle, the front axle is more or less typical of designs in Class 1. As shown in Figs. 2, 3 and 4, however, only one universal-unit is employed in each wheel. This is an unusually large universal-joint with the yoke bearings on a diameter almost equal to that of the wheel itself. The steering-knuckle pivot is at the center of the wheel and in the same plane as the universal-joint bearings. This involves the use of wheel bearings of very large diameter, and is a heavy construction which adds considerably to the unsprung weight, but it seems well suited to the heavy trucking service for which it is designed. Apparently, it does not permit a very large steering-angle, but it has the advantage of placing the universal-joint pivots at such a large diameter that the bearing pressures on them are relatively low.

[5] See *Automotive Industries*, March 10, 1921, p. 546.

[6] See *Automotive Industries*, June 4, 1927, p. 831.

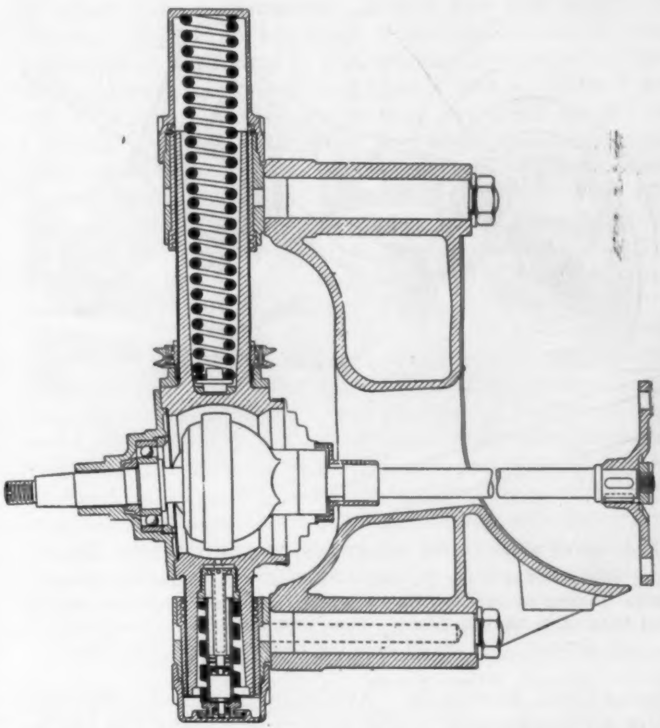


Fig. 15—Sectional View of the Kamm Front Drive

The Steering-Knuckle Is Guided by Brackets Attached to the Stiff Frameless Body. The Wheels Are Individually Sprung. In Principle, the Construction Is Similar to That of the Tracta, but the Structure Itself Is Very Different. Both Designs Have Coil Springs above the Steering-Knuckles

Another example of a design falling in Class 1 is one of the few French front-wheel-drive cars, known as the Bucciali, in which, according to *Omnia*, a French periodical, the front axle is connected to the engine by a short universal-shaft. The axle center is similar to those used in conventional rear axles. The entire front-axle assembly is unsprung. The car is in very limited production. Details concerning its construction are lacking but, according to the article by P. M. Heldt[6], the engine, clutch and transmission form a unit.

As shown in Fig. 5, the front springs are of the semi-elliptic cantilever type and are arranged at an angle to the longitudinal axis of the chassis. The rear ends of the springs extend through slots in the web of the frame channels, the center mountings being just outside this channel as shown. The springs are jointed to the trumpet-shaped axle tubes at their forward ends. Universal-joints are said to be "enclosed in the steering-knuckles in the usual way."

Designs Typical of Class 2

In Class 2 is included what is perhaps the best-known American front-wheel drive for passenger-cars; namely, that used on the Miller racing-car and shown in Fig. 6. The steering-knuckles are pivoted to a tubular carrying member which is bow-shaped in plan view and passes around the front of the car. To this front axle are welded shackles which are attached to four short quarter-elliptic springs, two on each side of the chassis, and arranged so that two are above and two below the axle. With this construction the unsprung weight is not much greater than that of a

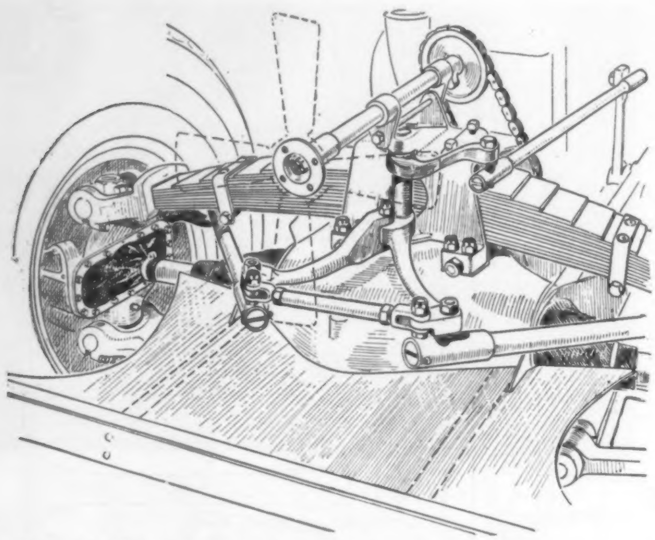


FIG. 16—FRONT-DRIVE ASSEMBLY OF THE UPPERCU COACH
This Design Was Used on Early Models. The Steering-Knuckles Were Connected to the Chassis by the Heavy Transverse Spring and Hinged A-Shaped Links. The Central Housing Is Carried on the Frame. The Novel Steering-Layout Should Be Noted

conventional front-axle. Although the outer universal-joint adds somewhat to the unsprung weight, the brake-drums are not on the wheels but are carried on the chassis at each side of the differential; hence, there is an offsetting gain on this score. This is a Ruckstell axle which incorporates either two or three gear reductions inside the axle housing itself, that is, one casing houses both differential and transmission gears. These are carried on the chassis frame and their weight therefore is sprung.

This same type of Ruckstell axle is used also in the new Marmon racing-car design, views of which are shown in Figs. 7, 8, and 9. The universal-joints employed in Marmon cars are of the Weiss design, shown in Figs. 10 and 11. This universal-joint possesses the peculiar advantage of transmitting a uniform angular motion between two shafts set at an angle to each other, which is not true of universal-joints of the conventional type. The yokes do not carry pins and bushings, as in the conventional type, but bear upon steel balls resting in suitable grooves cut in the yokes themselves. Because this joint transmits uniform angular motion, it is particularly well adapted for use in a front-wheel drive. The joints also take up a certain amount of end motion through the rolling of the balls in their raceways; hence, under certain conditions, no square or splined slip-joint is required and a rolling contact is substituted for sliding contact.

In the Marmon design the front end of the engine is bolted directly to the differential case, and the gearset itself does not increase the over-all length of the assembly. The radiator is placed immediately above the differential housing. With this arrangement applied to a conventional chassis, neither the wheelbase nor the over-all length would be materially increased as compared with a conventional rear drive.

DESIGN OF THE WALTER TRUCK

In the Walter truck we have another embodiment of Class-2 design in which the differential is mounted on the frame and the two steering-knuckle pivots are connected by a rigid carrying-member, as shown in Fig. 12. In this case the axle center is designed more nearly like a conventional front-axle, and is placed underneath the differential housing. Two gear-reductions are used, the second one being inside the wheel. This makes it possible to place the transverse universal-joint shaft well above the center of the wheel and makes the torque which this shaft and universal must transmit less than if the total reduction were made at the differential. The universal-joint shafts run at a slower speed than that of the crankshaft, due to the primary reduction between the bevel-drive pinion and gear, but at a higher speed than the wheels.

As compared with a hollow axle carrying a differential, the Walter form of construction seems to have some advantages on the score of less unsprung weight, despite the fact that an internal gear and pinion must be carried inside each wheel. A similar axle is used at the rear of this truck, but no steering-knuckles are provided because steering is done by the front wheels only.

FRENCH TRACTA DESIGN

One of the few and recent French front-wheel-drive designs is that known as the Tracta, shown in Fig. 13. It has individually sprung front wheels with knuckle-pivots connected by two horizontal tubes, one above and one below the center line of the wheels. These tubes are a part of the sprung weight. The total unsprung weight is made up of the wheels, outer universal-joints, steering-knuckles, and live-axle ends. Fig. 14 shows details of the universal-joints and their housing. This joint seems to be a double type and is said to transmit a uniform angular motion between the two shafts which it connects. The springs are of helical form enclosed

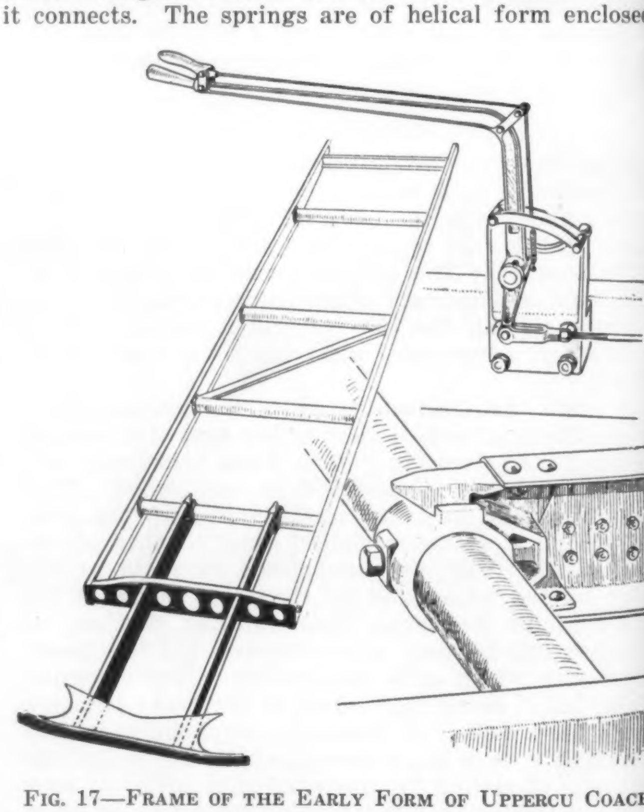


FIG. 17—FRAME OF THE EARLY FORM OF UPPERCU COACH
The Sub-Frame Carries the Powerplant and Driving-Gear Assembly. It Is Made So As To Be Quickly and Easily Detached after Loosening Two Bolts, One of Which Is Shown in the Drawing at the Right

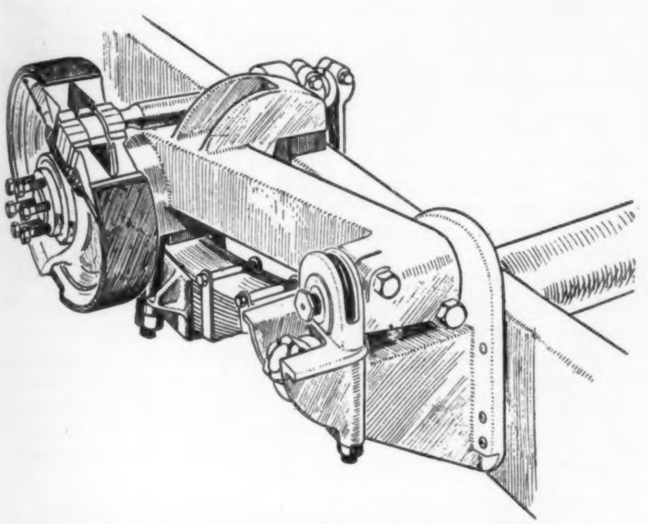


FIG. 18—NOVEL METHOD OF MOUNTING REAR WHEELS ON THE UPPERCU COACH

The Wheel-Spindle Is Carried at the Rear End of the Box-Section Radius-Arm Which Is Pivoted to the Frame. There Is No Rear Axle in the Ordinary Sense of That Term

within the cylindrical housing above the steering-knuckle pivot. On the whole this seems to be a clean design which is worthy of close study.

THE KAMM, A GERMAN DESIGN

A German front-wheel-drive car described by Mr. Heldt[7] is that known as the Kamm, in which the body itself serves as a frame and also provides the guides for the mounting of independently sprung front and rear wheels. Fig. 15 shows a sectional view of the front-wheel supporting-bracket and the front-wheel drive. The suspension is by a long coiled spring above the steering-knuckle, with a shorter helical spring below. The two universal-joints at each side of the differential case are of the fabric type, but the two inside the wheels are of all-metal construction and are enclosed in a spherical housing. The universal-yoke bearing-axes lie in the same plane as that of the knuckle-pivot axis. The short spindle-shaft is supported in a single ball-bearing and is keyed to the wheel hub, which latter is supported in a ball-bearing mounted on the outside of the spindle.

CLASS 3 TYPES WITH NO DEAD AXLE

The Class-3 types without the dead axle seem to me to be the most promising of all front-wheel-drive designs for passenger-cars, and interesting details regarding American, British, Italian, French and German designs are illustrated herewith.

A most interesting American design in this class has been applied thus far only to motorcoach chassis, although it seems to be adaptable also to other classes of vehicle. I first saw this design in October, 1924, and prepared a description which was published at that time[8]. The vehicle incorporating this design then was called the Uppercu Coach. (See Figs. 16, 17 and 18.) The design was the work of W. H. Douglas and his associates, and since has undergone some extensive revision. The reasons for these changes are interesting as showing what experience with this type of design has brought forth. The chassis, as described, was one of the first experimental models. The powerplant and driving mechanism were, and still are, made as a separate unit which can be disconnected by loosening two bolts; it can then be rolled out from under the chassis. This unit includes not only the engine but the clutch, the gearset and the differential, as well as the parts which take the place of the front axle. As originally designed, the powerplant was placed in conventional position with flywheel and gearset located at the rear. The drive was then taken by a wide silent chain to a countershaft running underneath the engine to the differential attached to the front end of the frame. From the differential, the drive was taken by two universal-joint shafts direct to the wheels. There was no front axle in the ordinary sense of this term.

The weight-carrying member was a heavy transverse spring, the outer ends of which were pivoted to the upper ends of the steering-knuckles. The lower ends of the knuckle-pivots were positioned by A-shaped links, the wide ends of which were hinged to the chassis. Instead of being carried on a through axle, the rear wheels were carried on stub axles at the end of two box-section arms pivoted to the main frame of the chassis. This made it possible to use a level body-platform very close to the ground. The platform required no bumps or raised portions in the floor to permit axle motion. The low floor gave ample ground-clearance and also made possible a body with ample headroom but with a roof considerably lower than in

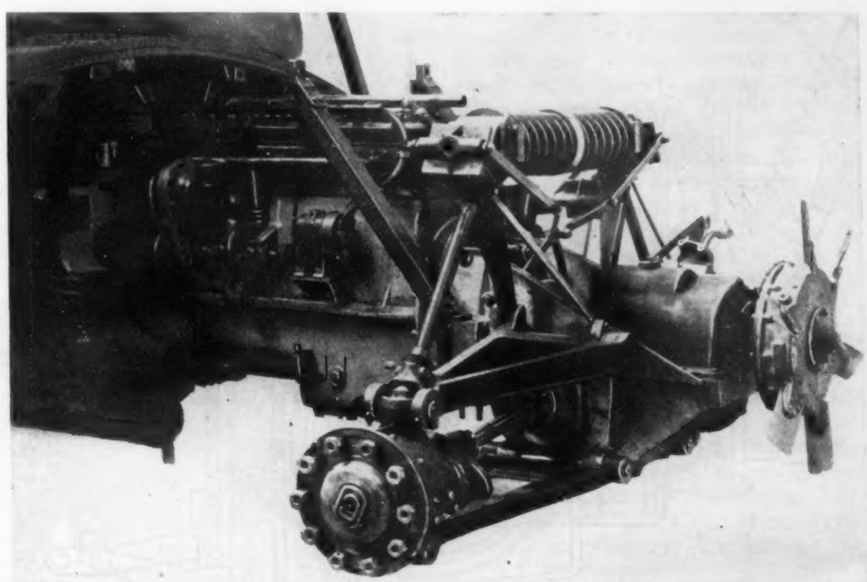


FIG. 19—HEALEY-AEROMARINE POWERPLANT AND FRONT DRIVE

The Novel Form of Springing Which Takes the Place of the Transverse Spring Formerly Employed on the Uppercu Coach Should Be Noted; Also, the Location of the Gearset, the Clutch and the Fan. The Knuckles Are Positioned by the Links Hinged to the Frame. The Strut and the Secondary Link Which Transmit Wheel Deflections to the Horizontal Helical Spring Are Evident

[7] See *Automotive Industries*, June 4, 1927, p. 831.

[8] See *Automotive Industries*, Oct. 16, 1924, p. 678.

conventional body-designs. Quick detachment of the complete powerplant and driving mechanism made it easy to substitute spare units, and thus keep a fleet of vehicles in continuous productive operation without the loss of time ordinarily occasioned by periodic repairs.

In the Uppercu Coach design the front wheels could be turned to an angle of 53 deg., and a chassis of 220-in. wheelbase could be turned around in a 50-ft. street without backing. The actual turning-radius was 28 ft.

As is evident in Figs. 19 to 23, which show the later design referred to here as the Healey-Aeromarine, the engine has been turned around so that the flywheel is in front. The drive is taken through a short propeller-shaft and a hollow worm and gearset shaft to the clutch, which is mounted in front of the gearset and directly behind the fan and radiator. From this clutch the drive is back again to the four-speed gearset, and thence in conventional fashion to the worm itself. Universal-joint shafts connect the differential to the front wheels, this arrangement being similar to the earlier layout except that metal universal-joint housings are substituted for the leather boots formerly used.

In place of the transverse spring originally employed in the Healey-Aeromarine design, a horizontal helical spring is substituted. The steering-knuckles are positioned by two A-shaped links at each side, the wide ends of these radius members being hinged to suitable lugs attached to the powerplant. Attached to each of the upper radius-members is a strut and a secondary hinged arm arranged so that the upward pressure of the knuckle produces inward pressure against a transverse helical spring. The other end of this spring is positioned against a similar strut on the other side so that the reaction is taken by the other wheel and not by the frame, as was the case with the heavy transverse spring used in the original design. Mr. Douglas kindly has furnished the following particulars concerning the latest design, and the reason for changing from the earlier one:

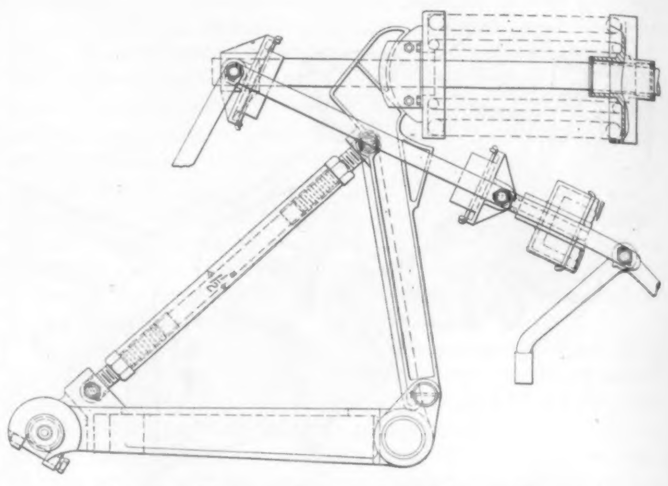


FIG. 21—HEALEY-AEROMARINE FRONT LINKAGE

The Linkage Takes the Place of a Front Axle. Upward Displacement of the Wheel Causes the Knuckle, the Upper End of Which Is Supported by the Lower Link, To Move Upward Also. The Strut Transfers This Movement to the Vertical Link, Which Bears Against the Horizontal Helical Spring. The Helical Spring Reacts Through a Similar Linkage to the Other Knuckle. The Small Shaft Carries Rubber Blocks or Bumpers Which Prevent Excessive Motion

> The main reason for departing from the system of drive described in *Automotive Industries* of Oct. 16, 1924, was to secure better distribution of weight, less destructive effects on the body due to torsional stresses chargeable to the front cross-spring suspension, and the excessive cost of the chain case and other members involved. The front suspension as originally constructed with leaf cross-spring and radius-arms was also expensive and, in addition, it was found difficult to obtain sufficient clearance for the steering linkage and drive-shafts under full spring-compression and rebound.
>
> In the 25 motorcoaches built for the New York Railways Co., we used a girder type of body of sufficient rigidity to discard the conventional frame members entirely. This construction gave a floor height of 14 in., with adequate road clearance. The original power unit with the propeller-shaft under the engine would have been too high in connection with a body of this descrip-

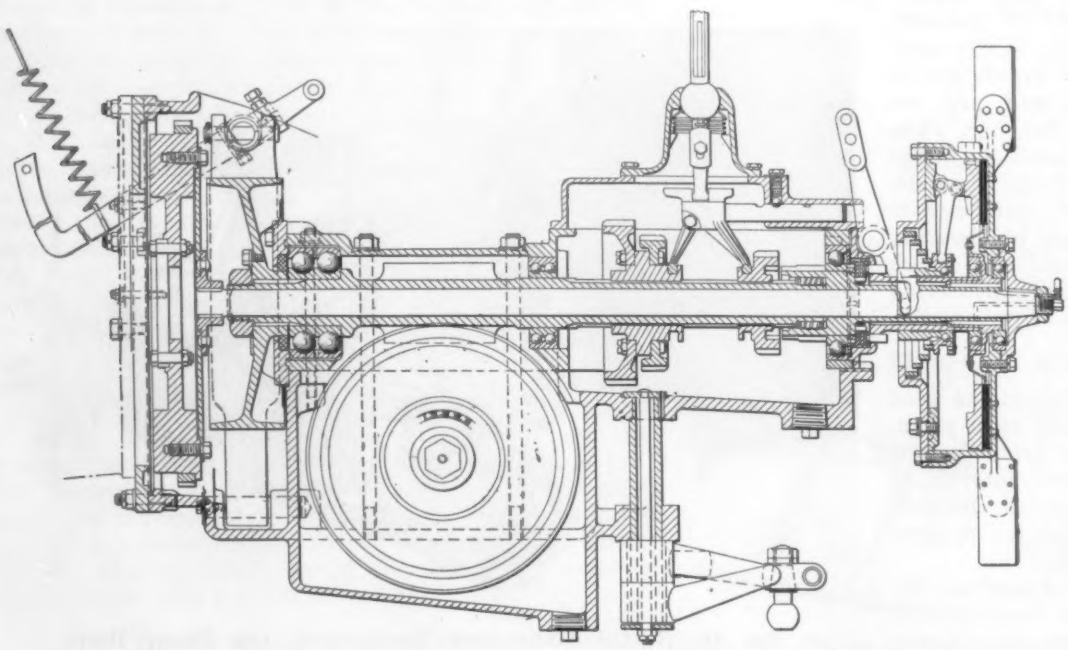


FIG. 20—HEALEY-AEROMARINE CLUTCH, GEARSET, AND WORM DRIVE-GEARS

The Flywheel at the Left Drives, Through a Flexible Coupling, a Propeller-Shaft Which Runs Through the Hollow Worm and Gearset Shafts to the Clutch Attached to the Fan at the Right. Thence, the Drive Is Back Through a Fuller Gearset to the Worm in Conventional Fashion. Part of the Steering Linkage Is Mounted below the Gearset

tion, and this was another reason for the new design.

The present powerplant, shown in Fig. 19, is made up of a conventional engine turned around so that the flywheel faces forward. An aluminum casting bolted thereto, which contains the worm drive and gearset, has lugs to which the radius-arms are pivoted. The propeller-shaft is flexibly connected to the fly-wheel and passes through a hollow worm and gearset shaft to the clutch, which is located at the extreme front. The torque is transmitted back through the gearset to the worm.

The clutch housing, with fan vanes attached thereto, and the gearshift lever, projecting outwardly from the gearcase in the left side, are shown in Fig. 20. A straight rod connects this lever with a conventional gearshift lever located in the usual position in relation to the driver's seat. The clutch is similarly actuated by rod connection to a pedal located in the usual position.

The helical-spring suspension shown in Fig. 21 is a recent invention of ours and has much to recommend it. The total weight is only about one-third that of a cross-spring suspension. With this spring we obtain a perfect three-point suspension throughout the full spring range until the bumpers contact, and no body-twisting strains occur until then. As the reactions are against the opposite wheel in the event of one wheel striking an obstacle, the entire spring is in use to absorb the shock. If impact is equal and simultaneous on both wheels, the spring absorbs both loads. The front-wheel assembly is shown in Fig. 22, and the steering-linkage in Fig. 23.

We tested the first vehicle of the late design with a dead load of 13,000 lb., the gross weight being more than 26,000 lb., driving it 24 hr. per day over back-country roads for more than 20,000 miles. During this mileage rain, snow and icy roads were encountered,

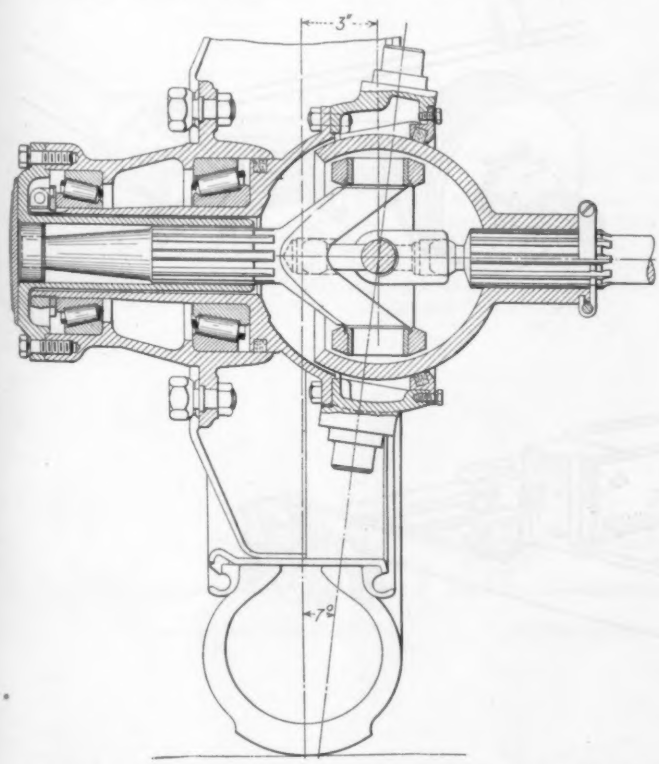


FIG. 22.—HEALEY-AEROMARINE FRONT-WHEEL, STEERING-KNUCKLE, AND UNIVERSAL-JOINT ASSEMBLY

This Universal-Joint Permits the Wheel To Be Cramped Through an Angle of 53 Deg. without Variation in Uniform Angular Velocity

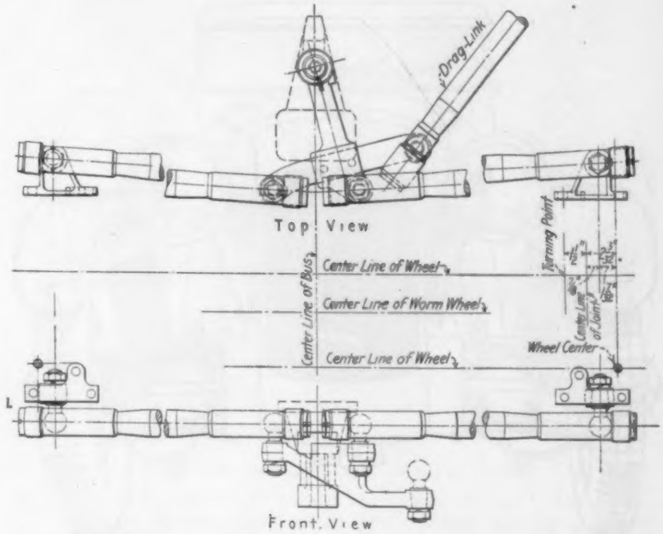


FIG. 23—HEALEY-AEROMARINE STEERING-LINKAGE

The Cross-Link or Tie-Rod Is Made in Two Parts To Avoid Interference with the Wheels, Which Have a 53-Deg. Steering-Angle, and To Accomplish Other Purposes as Explained in the Text

and the performance fully justified our faith in the front-wheel drive system.

Among the other interesting and important features of the Healey-Aeromarine front-drive design are the universal-joints used inside the front wheels, Fig. 22, and the layout of the steering-system, Fig. 23. Concerning the drive, Mr. Douglas furnishes the following particulars:

> The axis of rotation of this member—the ring member which is the equivalent of an intermediate shaft between two universal-joints — with respect to the driving and the driven members must lie in the plane of the paper for the position shown in Fig. 22. The axis between the ring and the driven member is shown on the drawing. The co-plane axis between the intermediate member and the driving member is obtained by a block and trunnion or De Dion type of joint which is hidden by the ring in the drawing. This combination has many advantages over the double construction which has been suggested in that it provides maximum spread for the joint bearings of both driving and driven elements, giving minimum bearing loads for a given size of joint. With any double type of joint, controlling means must be provided to assure that the intermediate members will make equal angles with the driving and driven members at all joint-angles. As this controller is subject to torque nearly equal to the maximum wheel-torque under certain conditions and must go inside of the joint with a bearing in the ring and in each of the other elements, its design presents a difficult problem.
>
> We have developed four different types of controller. The original types were composed of three or more pieces and it was found practically impossible within the available space to make them strong enough to stand up under extreme conditions. The two-piece controller shown in Fig. 22 was then developed and proved entirely satisfactory. The latest type is a single piece, which is cheaper.
>
> To test these controllers for motorcoach service the vehicle was placed on a dry concrete floor with the rear wheels locked and loaded with 13,000 lb. of steel. The front wheels were turned to the maximum angle of 53 deg., low gear was engaged and full power applied for several minutes. The results were that the entire vehicle would describe an arc about some cen-

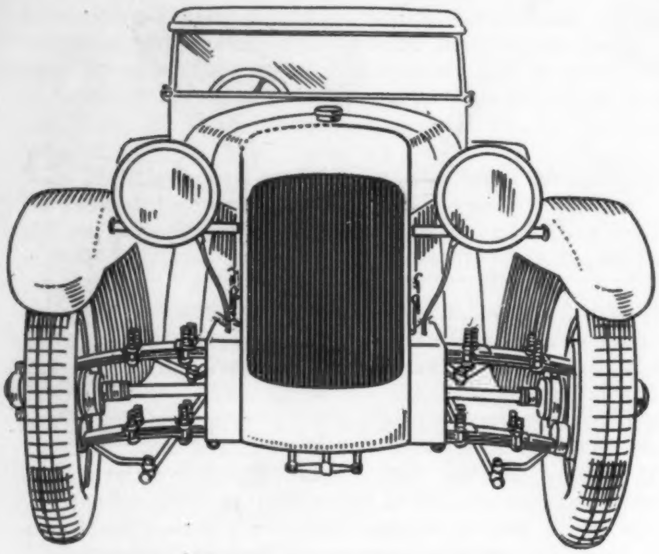


FIG. 24—THE ALVIS, A BRITISH DESIGN

The Two Drag-Links of the Steering-System Indicate Some Form of Dual Steering-Control Such As Is Considered Desirable with Independently Sprung Front Wheels

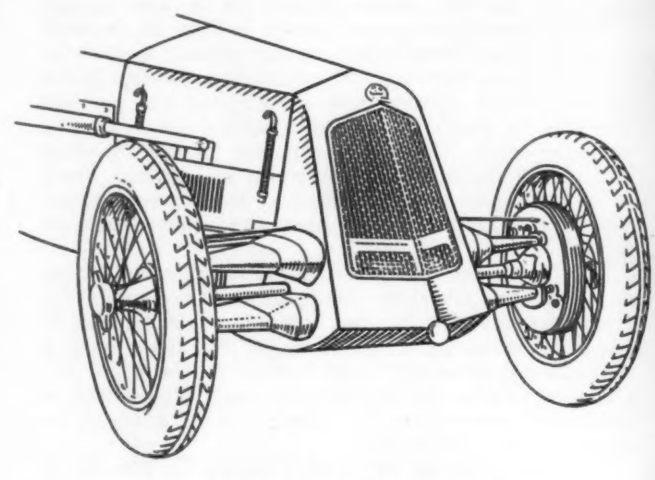


FIG. 26—ITALA RACING-CAR DESIGN

This Is Another Example of the Type of Designs Grouped in Class 3. In This Case the Transverse Quarter-Elliptic Springs above the Live Axle Are Fairly Wide at Their Inner Ends and Are Mounted between Rubber Blocks. Links Are Used Below the Axle. The Sheet-Metal Coverings Are Designed To Reduce Wind Resistance

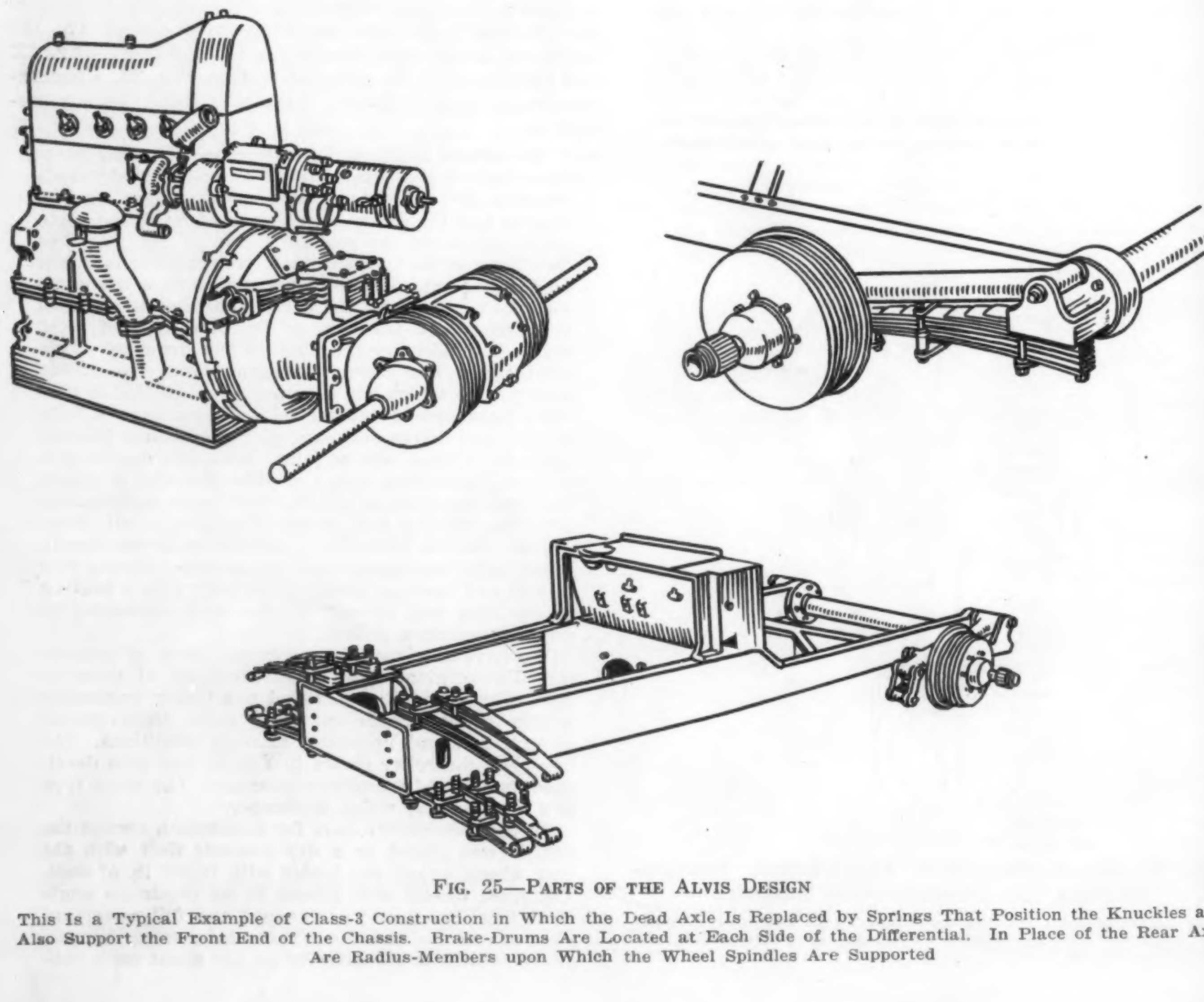


FIG. 25—PARTS OF THE ALVIS DESIGN

This Is a Typical Example of Class-3 Construction in Which the Dead Axle Is Replaced by Springs That Position the Knuckles and Also Support the Front End of the Chassis. Brake-Drums Are Located at Each Side of the Differential. In Place of the Rear Axle Are Radius-Members upon Which the Wheel Spindles Are Supported

ter located within the rear-wheel tread and wear off about ½ in. of the front tires. We made this test several times with an old set of front tires before putting the vehicle through 20,000 miles of road testing.

To prevent undue reactions on the steering-mechanism, the point of intersection of the steering-knuckle axis with the road must not be more than ½ to ¾ in. from the center line of the tire. With a wheel camber of 3½ deg., a steering-knuckle-pivot side-rake of 3½ deg. gave very satisfactory results and permitted an offset of the steering-knuckle axis of not more than ½ in.

The provisions for a grease-and-dust-tight construction are shown also in Fig. 22. Leather boots were found to have short life.

Steering the front-wheel drive presents two problems which are very satisfactorily met in our construction. To obtain large angles of steering, it is impractical to use a straight tie-rod between the wheels. If placed behind the axle, a tie-rod would interfere with the tire rims and, if placed in front, the arm at the wheel would have to project through the wheel to give the proper relative angles of the two wheels. We use two short cross-links, one to each wheel, which are connected to a horizontal bell-crank at the middle of the vehicle which is in turn linked to the steering-gear. With correct pivot-points at the wheels and bell crank, the proper wheel angles are obtained without interference. The second problem is to compensate for the in-and-out movement of the wheel hubs at bumps and rebounds caused by the radius-arm type of suspension. This is also solved by the double cross-links having properly located centers.

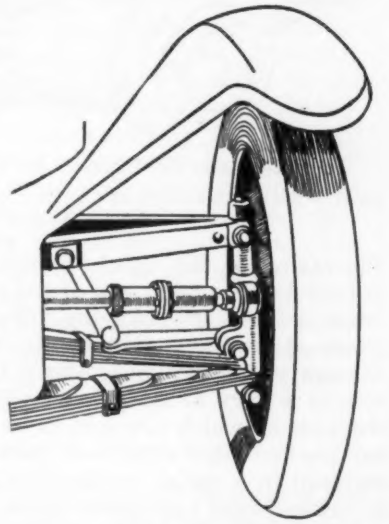


FIG. 27—THE ED. PARVILLE DESIGN, A FRENCH ELECTRIC FRONT-DRIVE

The Two Quarter-Elliptic Springs Are Not in the Same Vertical Plane; the Inner Ends Are Separated As Seen in Plan View and the Outer Ends Come Together at the Steering-Knuckle. At the Top the Knuckle Is Pivoted to the Outer End of a Triangular Link Which Is Hinged to the Frame

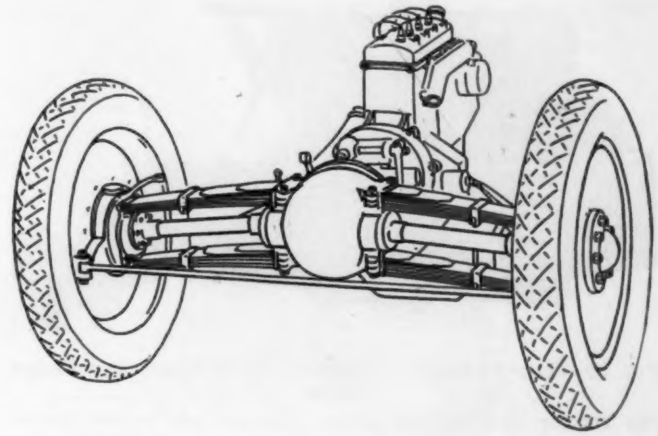


FIG. 28—THE VORAN, A GERMAN LIGHT CAR

The Detachable Front-Drive Unit Is Shown. Each of the Knuckles Is Supported by Two Quarter-Elliptic Springs and by a Radius-Member Pivoted to a Point on the Powerplant Near the Flywheel Housing

The only British front-wheel-drive passenger-car about which particulars are available is the Alvis, a development of the Alvis racing car. (See Figs. 24 and 25.) In general this design is similar to the Miller and the Marmon designs in America, except that, instead of using a dead axle to connect steering-knuckles, these are supported on four short transverse quarter-elliptic springs on each side of the frame, the two in each pair being placed far enough apart in plan view to provide the requisite stiffness against fore-and-aft shocks when the front wheels strike obstacles. Full details concerning this design are not at hand, but the published sketches show what seem to be two independent drag-links, indicating that a dual steering-system is employed. This is in line with experience cited by M. de Lavaud in other designs having independently sprung front wheels. There is no rear axle in the ordinary sense,

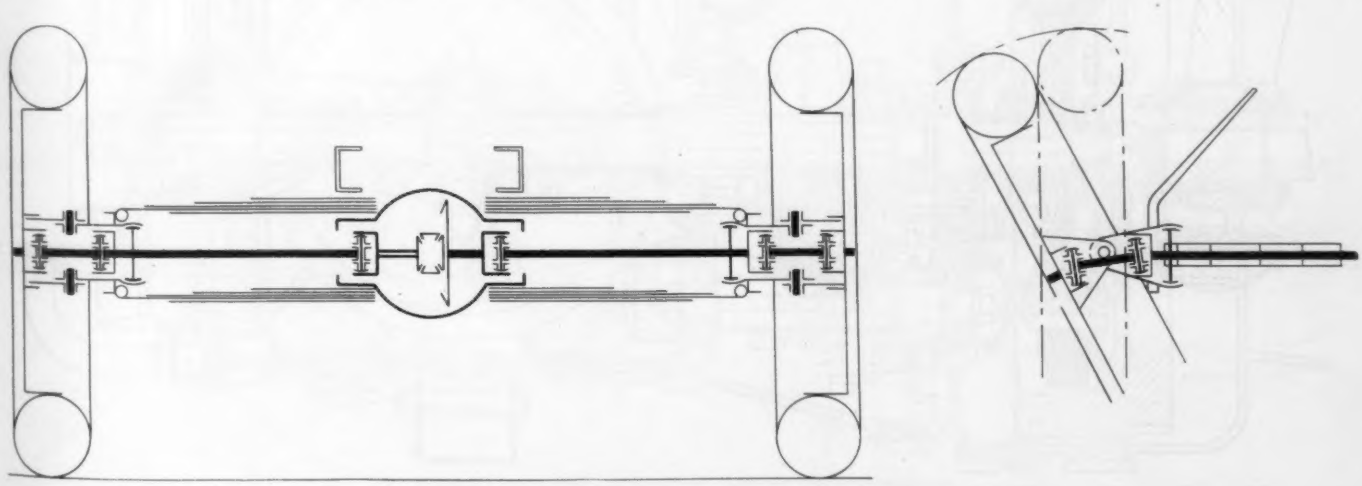


FIG. 29—DIAGRAMMATIC ARRANGEMENT OF THE VORAN DESIGN

The Front Drive Has Two Universal-Joints at Each Wheel. These Are Placed Equidistant from the Steering-Knuckle Pivot and, Since Each Drives Through the Same Angle, the Angular Velocity Is Said To Be Uniform

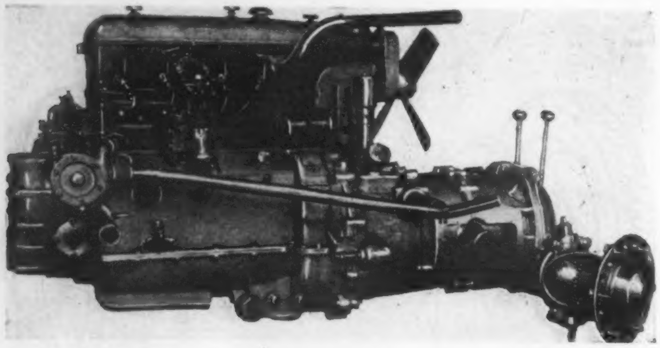


FIG. 30—THE RUMPLER COMBINED POWERPLANT AND FRONT DRIVE

The Tubular Axle-Ends to Which Knuckles Are Pivoted Swivel Independently Around the Axis of the Propeller-Shaft When the Wheels Are Displaced

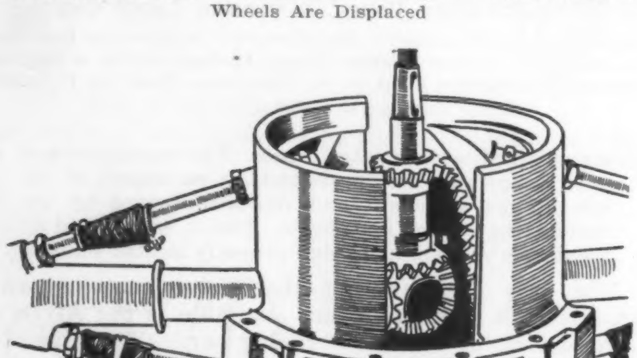


FIG. 31—THE RUMPLER DIFFERENTIAL HOUSING

Note the Two Sizes of Bevel Gearing and the Cylindrical Segments Which Swivel, Under Spring Action, Together with the Tubes Through Which the Live Axles Pass

the wheels being mounted at the ends of radius-arms pivoted to the frame and reacting against short quarter-elliptic springs. This unusual springing at the front and the rear is said to provide unusually easy riding-quality and to enable the car to negotiate turns at a much higher speed than is safe with an ordinary rear-drive car.

ITALA RACING-CAR DESIGN

Published descriptions of this and of several of the other designs referred to subsequently are rather meager in detail. In the Itala design shown in Fig. 26

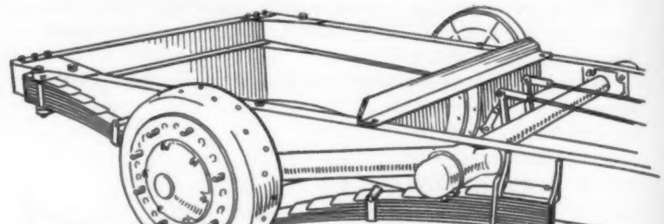


FIG. 32—REAR SUSPENSION ON THE RUMPLER CHASSIS

Each Wheel Is Mounted at the End of a Radius-Member and Is Supported by Two Quarter-Elliptic Springs

the casing of the clutch, transmission and differential is bolted to the front end of the engine. The two transverse driveshafts from the differential have universal-joints at each end, that at the inner end providing for necessary end-motion. Above the driveshaft at each side is a very broad quarter-elliptic cantilever spring, the ends of which are said to be mounted between rubber blocks. As will be seen from Fig. 26, this spring is enclosed in a metal housing designed to protect it and to reduce wind resistance without interfering with its

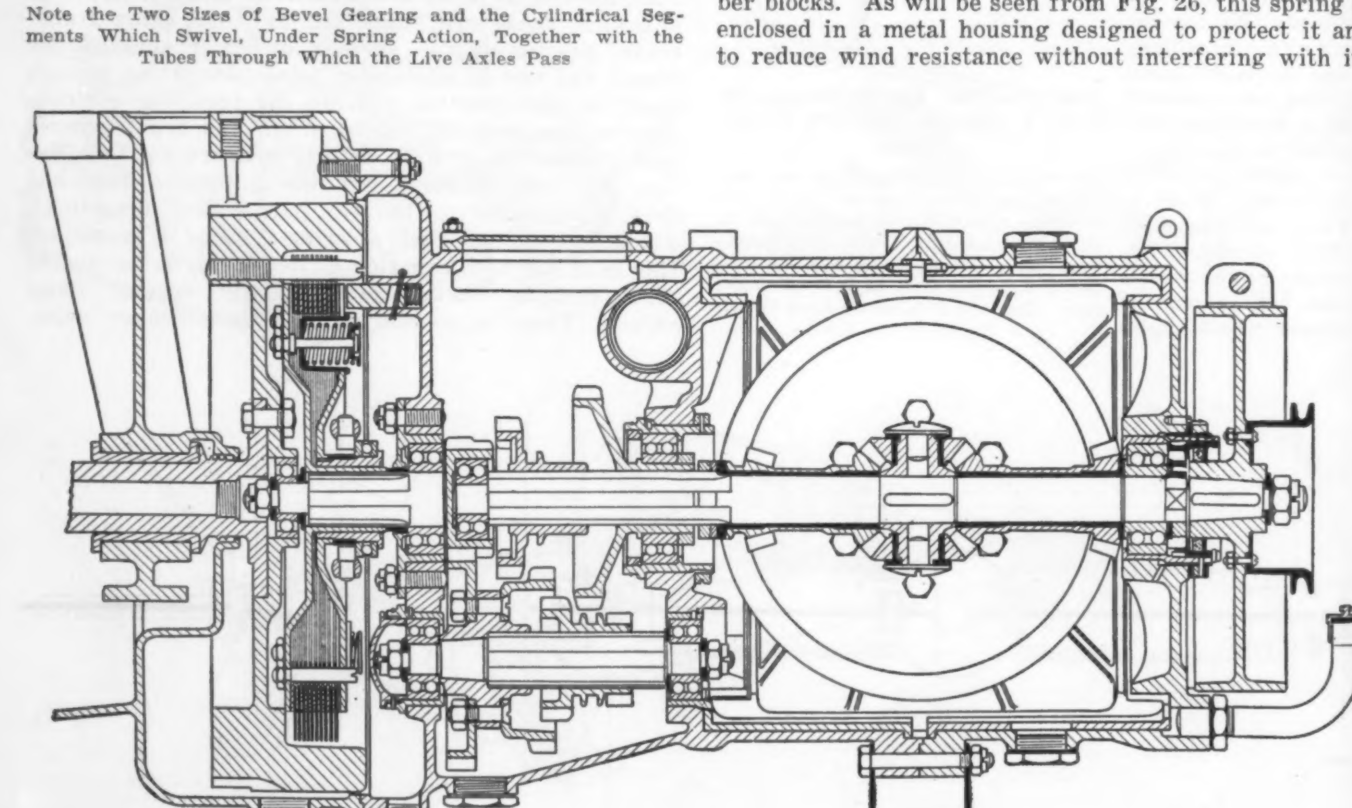


FIG. 33—RUMPLER CLUTCH, GEARSET, FINAL DRIVE AND BRAKE-DRUM

The View Is a Vertical Section. The Two Sizes of Bevel Gear, the Oscillating Cylindrical Segments, and the Front Mounting of the Brake-Drum Are Shown

free motion. Connection between this casing and differential housing is made by a broad rubber-band. A similar construction is used below the driveshaft, except that in place of the cantilever spring there is a rigid beam with a spring mounting at each end. An apparently similar structure is used in place of a conventional rear axle.

Two French Front-Wheel Drives

According to the best information available, there are only four makes of French front-wheel-drive vehicle in the market. One of these is the Latil truck, which has been in the market for some 20 years. Others are the Tracta and the Bucciali, already described. The remaining one is an electric vehicle known as the Ed. Parville.

In the Ed. Parville electric vehicle the steering-knuckle at each side is supported by two quarter-elliptic springs, the inner ends of which are fastened to the driving-gear housing. Although Fig. 27 does not appear to show it, these two springs are said to be approximately in the same plane but not parallel to each other. In other words, the two inner ends are separated and the outer ends come together at the point at which they are attached pivotally to the steering-knuckle. The upper end of the steering-knuckle is connected to the driving gear by a triangular link somewhat shorter than the springs. Springs and links together hold the steering-knuckle in a vertical position, while the triangular link and converging springs give the necessary stiffness in a horizontal direction.

Three German Front-Wheel Drives

The Voran is a light car having a 25-hp. engine and a chassis of 106-in. wheelbase. (See Figs. 28 and 29.) The entire powerplant, including engine, gearset, and clutch—as well as the differential, driveshafts, springs and wheels—are combined into a unit which can be quickly rolled out from under the car and replaced by another similar unit if desired. At each side of the differential are two quarter-elliptic springs, one above and one below the driveshaft, the outer ends of which are attached to the steering-knuckle, which is braced against fore-and-aft stresses by radius-rods extending backward to points on the powerplant approximately opposite the flywheel housing. A particularly interesting feature of this unit is shown in Fig. 29. Two universal-joints are used at the wheels, these being connected by a short shaft. The universals are spaced

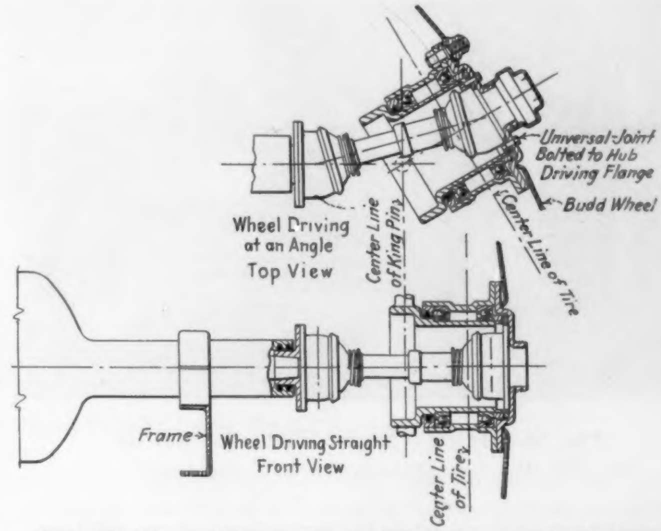


FIG. 35—FRONT-WHEEL-DRIVE DESIGN OF C. R. ROCHE

The Universal-Joints Are Arranged Equidistant from the Knuckle-Pivot, the Design Being Similar in This Respect to the Voran, So As To Avoid Fluctuations in Angular Velocity and To Limit the Angle to One-Half That Which Occurs with a Single Joint. A 3100-Lb. Test-Car Using 5-In. Spicer Joints Is Reported To Have Run 130,000 Miles Without Requiring Any Repair or Adjustment to the Front-Drive Mechanism

FIG. 34—LA VIOLETTE, AN EXAMPLE OF CLASS-2 DESIGN

The Location of the Universal-Joint and the Steering-Knuckle Pivot Inside the Front Wheel Should Be Noted, and Also the Arrangement of the Gearset, the Worm Drive and the Propeller-Shaft Brake

FIG. 36—HAMLIN FRONT-DRIVE RACING-CAR
This Car Was Seen at the Indianapolis Speedway in 1926

equidistant from the steering-knuckle pivot, an arrangement said to transmit uniform angular motion to the wheel. The outer end of the axle shaft is supported in a spherical housing or bearing. The short shaft that connects the two universal-joints floats.

An unusual, and what seems to me to be an unnecessarily complicated, construction is that employed by Dr. Edwin Rumpler in a 50-hp. front-wheel-drive car. This drive, which is pictured in Figs. 30 to 33, is described by P. M. Heldt[9], as follows:

> The Rumpler axle construction is unusual in that the axle ends to which the knuckles are pivoted are carried by tubular members surrounding the drive shafts. These tubular members are not fastened rigidly into the central housing but have independent pivotal motion around the fore-and-aft longitudinal axis, or the axis of the propeller-shaft. This is made possible by mounting the differential gear on the propeller-shaft instead of on the driven shafts, and it is really around the axis of the differential gear that the two axle-halves swivel. Each axle shaft has its own bevel drive-gear, which is driven by a separate bevel pinion on one of the differential side-gears. To prevent interference between the two sets of bevel drive-gears, they are made different in size. The two axle-tubes are fitted into sectors located on the inside of the cylindrical housing over the differential. These sectors are comparatively wide and, in addition to the axle-tubes, two brace-rods are anchored in each to give the axle the necessary horizontal stiffness.
>
> The axle tube ends in a spherical housing which encloses a universal-joint connecting to the knuckle-shaft, and the joint evidently is working only when, in steering, the wheels are deflected from the straight-ahead position.
>
> At the front, the frame is supported on the axle ends by two pairs of transverse semi-elliptic springs. The propeller-shaft extends entirely through the drive-gear housing and carries at its forward end a large brake-drum to which a pair of contracting brake-shoes can be applied. The powerplant and front axle form a unit that can be readily replaced by another unit.

The longitudinal section view of the Rumpler clutch, gearset and differential in Fig. 33 shows also an arrangement of brake in front of the gearset which is one of the optional positions in which such a brake can be placed. It provides braking on the front wheels without locating the brake-drums on the wheels themselves and also equalizes the braking action. This is an interesting contrast to the Miller and the Marmon designs in which the brake-drums are placed on the driveshafts at each side of the differential housing.

Other examples of front-drive designs are shown and described in Figs. 34 to 38, being of the La Violette, the C. R. Roche and the Hamlin types.

UNIVERSAL-JOINT DESIGN

One of the important considerations in designing a front-wheel drive is to provide universal-joints that will give the desired uniform angular velocity. In this connection, I quote again from Mr. Heldt's paper[9], as follows:

> Of the two universals in each driveshaft, the one near the central housing has to take care only of the angularity due to spring play. Fortunately, the vertical play of the front spring is not very great, being

[9] See *Automotive Industries*, June 4, 1927, p. 831.

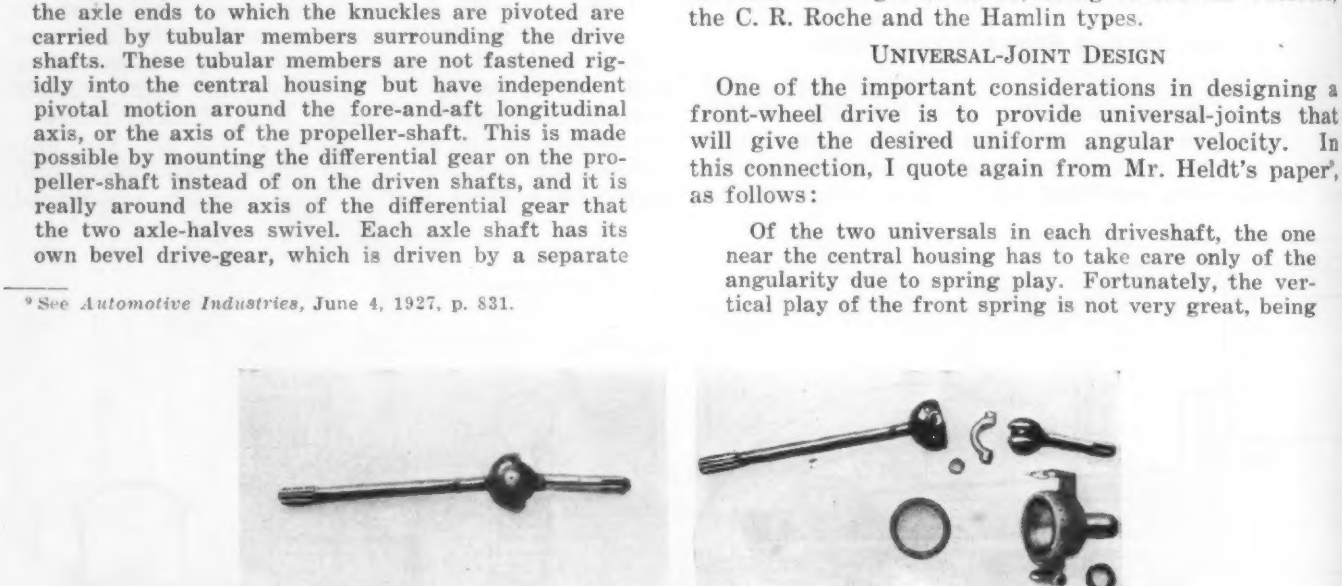


FIG 37—PARTS USED IN THE HAMLIN FRONT-WHEEL-DRIVE PASSENGER-CAR

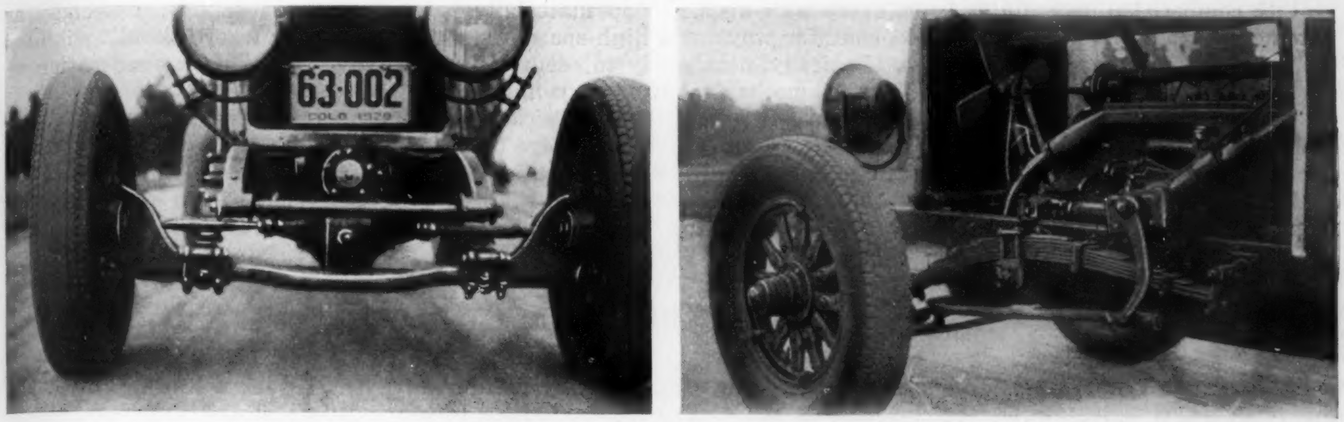


FIG. 38—THE 1928-MODEL HAMLIN FRONT-WHEEL-DRIVE TEST-CHASSIS

limited to about 2 in. on each side of the normal position. Moreover, spring play does not affect the parallelism between the differential shafts and the knuckle-shafts, and the angle between the differential-shaft and the axle-shaft is always the same as the angle between the axle-shaft and the knuckle-shaft; hence, the speed fluctuations created by one joint will be neutralized by the other.

It is different, however, with respect to the angularity between shafts due to steering motion. The angle of the steering-spindle with the axle may exceed 30 deg.; in fact, it may reach 40 deg. and, for such angles, there would be extreme fluctuations in the speed of the driven member if the speed of the driving member were constant. For an angle of 30 deg., for instance, the speed of the driven shaft would fluctuate through a range equal to 29 per cent of its mean speed.

Actually, of course, neither the driving nor the driven shaft would run at constant speed; but one would accelerate and the other would at the same time decelerate, and both would be subjected to very great stresses as a result of these accelerations and decelerations because of the heavy masses connected with them. It would therefore be desirable to use at the knuckle end of the axle-shaft either a type of universal-joint that is free from these periodic fluctuations, or else two joints located close together and symmetrically on opposite sides of the knuckle-pin axis when the wheel is in the straight-ahead position. Then, if the wheel is swung around for steering, each of the two adjacent universals will assume the same angularity, and the fluctuations in the transmission ratio due to the two joints will cancel out.

With Mr. Heldt's foregoing remarks in mind, it is interesting to note what steps have been taken in various designs to meet the conditions here outlined. One is to employ a type of universal-joint such as the Weiss, which provides a uniform angular velocity regardless of the layout employed. Much the same result is attained by the construction employed in the Healey-Aeromarine design, and it is claimed in the Tracta design which is, in effect, a double universal-joint. In the Voran design two joints are employed and they are placed equidistant from the steering-knuckle axis so that, it is contended, fluctuations of the angular velocity are cancelled out; but this contention seems to require qualification if the universals are of the conventional type with yokes connected to pins at right angles. In this case the variations in angular velocity cancel out when the two joints make equal angles with the shaft connecting them, as they seem to do in the Voran design. Apparently, however, the inner of the two joints in the wheel will impose a fluctuating velocity upon the shaft connecting it to the differential; but, since the angle at this joint is only half that through which the wheel is turned, the effect may not be serious.

Fig. 39 shows front-drive universal-joints of a type used in approximately 70 motorcoaches of 51 to 70-passenger capacity which have been operated millions of miles in Chicago. On the basis of this experience G. A. Green, of the General Motors Truck Corporation, says:

> No thoroughly satisfactory design has yet been developed which provides a driving shaft to each front wheel with two universal-joints incorporated. Any such arrangement results in undue tire wear, due to constant change in the angular velocity of the universal-joints.

SUMMARY

Concerning the future of front-wheel drives, we have seen that they present many advantages and that there is good ground for the view that the advantages outweigh the disadvantages; but it does not follow as a necessary corollary that front-drive cars will become the popular type or even that they will be adopted soon by many manufacturers. It is known, however, that at least three or four companies, including one or two prominent makers, are greatly interested in this type of drive and either have experimental cars well advanced or are planning to build them. One company is reported to have acquired the Miller patent-rights on front-wheel drives. It would not be surprising to see two or more front-drive cars offered at next year's shows if, indeed, some such designs are not marketed before that time.

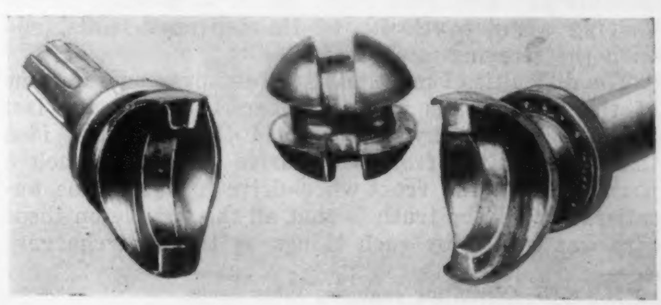


FIG. 39—TYPE OF FRONT-DRIVE UNIVERSAL-JOINTS USED IN CHICAGO MOTORCOACHES

With competition exceedingly keen, every wide-awake automobile manufacturer is on the lookout for ways of securing even a temporary advantage. Basically, nearly all American cars are very much alike in mechanical design and have been changed but little since the general introduction of four-wheel brakes. We are about due for some radical improvements in mechanical design, and it may well be that one of these will be the front-wheel drive. The fact that such drives appear to add materially to the safety of driving, especially at high speed and under conditions where skidding is likely to occur with rear-drive cars, is a consideration of primary importance.

In any case it will pay automotive engineers to keep a sharp eye on front-wheel drives, and to see that their experimental departments make searching investigations of all promising developments in this direction that indicate distinct advantages.

THE DISCUSSION

PRESIDENT W. G. WALL[10]:—Regarding the future of the front-wheel drive, when the automotive industry judges a subject worth attention, it generally takes it up rather quickly. If it were not for the fact that our needs and requirements change so rapidly we might say that the rear-wheel drive, like the sliding-gear transmission, will be with us always. But our needs do change and a present one, without question, is to have less unsprung weight on the axles. One of the most disagreeable features of riding in cars today is the shock caused by running over very small and abrupt chuck-holes.

The front-wheel drive affords one fairly easy means of reducing unsprung weight, although many designs have not made use of this possibility. I do not mean to say that, to a certain extent, we cannot do the same thing with rear-wheel drives; but, to make it acceptable in other ways, the front-wheel drive should and will have less unsprung weight.

One of the first things I did after becoming interested in the automotive industry was to make some drawings of possible methods of driving through the front axle. That was 30 years ago. During the war we used many four-wheel-drive trucks and experimented in disconnecting the rear-wheel drives and using the front-wheel drives only. I believe that the consensus of opinion was that better results were obtained with the front-wheel drives than with the two-wheel drives at the rear, and that the results were almost as good as with the four-wheel drive.

One of the disadvantages of the front-wheel drive has been the seeming necessity for a longer wheelbase. Apparently, this disadvantage can be avoided. A long wheelbase has an advantage, however, in that the engine is far enough back of the front axle to allow more space between the radiator and the engine for air circulation. It is well known that radiators are extremely handicapped by having the engines set so close that an insufficient amount of air gets through. Trouble has also been experienced on account of the varying angular velocity of the universal-joints, and with the steering-mechanism.

The difficulties I mention have been overcome in some of the late designs of racing cars. During the last 500-mile race, many persons had the erroneous idea that, because the front-wheel-drive cars made such a poor showing, the front-wheel-drive axle must be unsatisfactory. The truth is that all the trouble on these cars was caused by such things as the superchargers and leaky gasoline-tanks. In general, the trouble could not be charged to the front-wheel drive.

PROPULSIVE POWER REQUIRED

JOSEPH A. ANGLADA[11]:—Exponents of the front-wheel drive have asserted that less power is required to propel a car by the front wheels than by the rear wheels, but tests with an electric vehicle have disproved this. From 1905 to about 1912, Walter Christie built front-wheel-drive cars of the Class-3 type and they made fairly good records on the track. In 1910, when he built a front-wheel-drive taxicab and a front-wheel-drive touring-car of the Class-3 type, with a four-cylinder engine placed transversely on the front cross-member, these cars actually weighed from 10 to 15 per cent less than comparable conventional types of car. The increased wheelbase apparently necessary with front-wheel-drive cars can be avoided.

Front-wheel-drive cars will, I believe, enable us to use better spring-suspensions, because, with a radical change of drive, we shall have the temerity to get away from the conventional type of leaf-spring, with its limitations. My experience with various types of American and foreign front-wheel-drive cars shows that the troubles have not been with the front-wheel drive but with other parts of the car, due probably to the fact that the designers concentrated their efforts almost entirely on the front-wheel drive and neglected the conventional construction that they used for the other parts.

LEE W. OLDFIELD[12]:—After having had considerable opportunity to observe the development of front-wheel-drive racing-cars and being for some time extremely interested in the front-drive design, I am not certain that I am as interested at present as I formerly was. It is true that in the last 500-mile race there were no failures in the strictly front-drive mechanisms, but the failures of the supercharger drive-gears which predominated were mostly on cars having front-wheel drives. It is observable on the speedway that the front-wheel-drive cars spin their wheels very much more than do the rear-wheel-drive cars at the same speed. If an observer on the back-stretch of the track or on the home-stretch listens as the cars come past, he can hear definitely that the front-wheel-drive cars are not getting tractive effort because they are whining at different speeds.

The supercharger drive-gear failures are all on the deceleration side. Our company made many sets of gears for these cars last year and there were many failures. In some cases the gears were made as well as anyone knows how to make them, from S.A.E. 2512 steel, and were examined by competent authorities

[10] M.S.A.E.—Consulting engineer, Indianapolis.

[11] M.S.A.E.—President, Anglada Motor Corp., New York City.

[12] M.S.A.E.—Designing engineer, Package Car Corp., Chicago, Ill.

after the gears failed. All the authorities said that the gears were made as well as they could be made, and showed no evidence of heat or lack of lubrication; but the teeth were folded right over on the deceleration side. In my opinion, this is due to the fact that the front-wheel-drive cars do not get tractive effort when they are trying to accelerate and the wheels spin intermittently. With the supercharger running from 35,000 to 45,000 r.p.m., a sharp deceleration of the mechanism puts terrific loads on the drive-gear train. I am, therefore, not convinced that we can get adequate tractive effort with the front-wheel drive.

Skidding Tendency

I think there is no disputing Mr. Chase's statement that the cars follow the front wheels and have less tendency to skid, if we assume that the driver has the courage to keep his foot on the throttle. But I can assure you that if the driver takes his foot off the throttle he will immediately have something to think about. Just prior to the recent 500-mile race, Mr. Duray demonstrated that, with the foot on the throttle, the car will travel in the direction in which it is pointed. Pete DePaolo demonstrated that, with the foot off the throttle, the car will not travel in the direction in which it is pointed. The same thing was demonstrated by Harry Hartz on a board track last fall. Of course, such conditions are abnormal and speeds are extremely high, but these observations should give us something to think about.

Major E. G. E. Beaumont[13]:—After observation of the steps made in the past to produce a front-wheel drive, I note particularly some of the French designs; the Latil, for example, which I believe has useful application for commercial trucks. But there appears a possibility with most of the present designs of unduly compressing the space allowed for the transmission gear, and that some of the advantage of weight distribution and the utility of spacing the units properly will thus be lost. It seems to me that some of the advantages claimed for front-wheel drive can be applied equally to rear-wheel drive; for example, the arrangements of independent wheel-springing and the reduction of unsprung weight. But I agree with the previous speakers that the problem is still one that requires investigation. It remains a matter for most interesting speculation.

Herbert Chase:—We should be constructive about this matter of front-wheel drives and not destructive. A very bad situation is created if the conclusion is reached that a successful thing such as our present-day motor-car cannot be improved very much. It is not a foregone conclusion that the front-wheel drive will be an improvement, but it has possibilities which should be looked at from the constructive side. It would be very unfortunate to take the position that "front wheel drives are too complicated, why bother with them?" Many have taken this attitude and I was so inclined myself before I started to look into the subject. But when I began to analyze the problem, I found that it is possible actually to make a simpler construction with front-wheel drive than we have today with the rear-wheel drive. I have attempted to give the reasons in my paper.

President Wall and Major Beaumont are right in saying, as I also said in the paper regarding this question of unsprung weight, that it is possible to get many of the advantages cited as being in favor of front-wheel drives without actually having the drive itself. It is entirely feasible to retain a rear-wheel drive and have individual wheel-springing, thereby obtaining such a reduction in unsprung weight as is not possible, so far as I can see, by any other method. But it is true also that this type of springing lends itself especially well to use in front-wheel-drive designs; hence it is fair to credit certain types of front-wheel drive with the advantages of individual wheel-springing, just as it is proper to debit other front-wheel drives with increased unsprung weight.

Regarding Mr. Oldfield's remarks, if I gave the impression that front-wheel-drive cars will not skid under any conditions this certainly was not my intention, because it is very evident that front-wheel-drive cars can and do skid under certain conditions. But the concensus of opinion, so far as I have been able to learn, is that a front-wheel drive is less likely to skid than is a rear-wheel drive, probably because the driving force is in the direction in which the front wheels themselves, the driving wheels, are steered.

As already stated, the questionnaire on which my paper is based in part resulted in replies from many of the most prominent engineers in the industry. One of the questions was, "Do you think the advantages of the front-wheel drive outweigh the disadvantages?" Four replied "Yes," without qualification; one gave a qualified "Yes"; nine said, "No," without qualification; three said, "No," with certain qualifications; and three were uncertain or evasive.

Another question was: "What other major improvements do you consider more promising than front-wheel drives?" The various answers I received are: Short engine of high power; individual wheel-springing; better-controlled springing; free wheel-springing; lighter, faster cars; better riding and handling qualities; engines of very high speed equipped with cuff valves; radical changes in fuel-handling systems to improve thermal efficiency; two-speed axles or over-speed transmissions; worm drive; powerplant located at the rear on motorcoaches; six-wheel chassis with drive on the four rear wheels; automatic brake-adjustment; and developments involving omission of the present transmission, that is, substitutes for the present gearset.

[13] President, Institution of Automobile Engineers; motor superintendent, Anglo-American Oil Co., Ltd., London, England.

Symposium on Recent Motor-Vehicle-Inspection Procedure

Several phases of detailed inspection of motor-vehicles for maintenance and repair were presented at a meeting of the Southern California Section, and these were discussed following the presentation of the four papers which are printed herewith. These several phases are dealt with in a paper on the Inspection of Motor-Vehicles, in general, by P. H. Ducker; one on Inspection of Motorcoaches, by F. C. Patton; one on Inspection for Overhaul and Repairs, by James L. Ferguson; and a fourth on Maintaining Motor-Truck Axles, by C. H. Jacobson. Each paper is preceded by an abstract.

The discussion, which is general on all the papers, includes details relating to the bending of steering-knuckle arms, the desirability or otherwise of heating parts before straightening them, and statements regarding the averages of motorcoach breakdowns from tire failures. Practice regarding periodical lubrication for the different classes of motor-vehicle are stated briefly, and the special qualifications which inspectors and service men should have are outlined. General statements are made in conclusion regarding the present status of brake equipment, head-lamps, and regulations for motor-vehicles.

Inspection of Motor-Vehicles

By P. H. Ducker[1]

TWO types of organization are specified by the author; first, those responsible for the operation of a fleet of motor-vehicles in which all the equipment is housed at one location; and, second, those having a number of divisions scattered at various locations in the territory served. To care for the first group, usually comprising numerous motor-vehicles, it is best to employ a first-class inspector who is competent to advise mechanics how to eliminate the causes of troubles found. A supplementary procedure suggested is that the drivers make written reports to the inspector.

Various test procedures of a practical nature are suggested for locating trouble. Periodical inspection and the immediate remedying of troubles are recommended. In the author's opinion, careful periodical inspection in conjunction with reports from the drivers tends not only toward economy in the operation of the vehicle but also toward continuity of service.

Tire cost and compliance with State regulations must be considered in connection with tire inspection. An operator should avail himself of the experience obtained by the manufacturers in their laboratories and keep tires inflated to the recommended pressure. Solid-rubber tires are mostly affected by the State regulations in California. Flat spots are likely to develop on heavy-truck tires and these are injurious not only to the highways but to the vehicle. Inspection should cover this condition, so that the owner will not be required to pay for the consequences, either in high cost of operation or in police-court fines.

A MOTOR-VEHICLE is only as good as its performance proves it to be, reliability and consistency of service being its most valuable recommendations. Motor-vehicles are now being produced which embody the combined ideas of the designing engineer and the man in the field whose responsibility it is to keep them going. Until recently, the average automotive engineer at the factory rather resented ideas and suggestions from operators, feeling that most of the operators were guessing; but this situation has changed, and many new developments have been suggested to the engineers by field operators. There should be at all times close contact between the engineers and the operators; in fact, if the automobile companies would lay stress upon their engineers' contact with users, as they do in the sales department, better results would be obtained.

Why is the operator in a position to offer suggestions and ideas? Operating costs and lack of continuity of service constitute the answer. Either can be responsible for the success or failure of the man on the job. Proper inspection is one of the most important of the operators' problems, classified as inspection by specialists in (*a*) the service department of any automobile-selling organization, (*b*) at public garages and repair shops, and (*c*) by owners and users of motor-vehicles.

Inspection by Fleet Owners

Organizations responsible for the operation of a fleet of motor-vehicles are divided into two groups. The first is that in which all the equipment is housed at one location. The second is that in which the fleet has a number of divisions scattered at various locations within the territory served. To care for fleets in the first class, usually comprising numerous motor-vehicles, it is best to employ a first-class inspector or trouble-shooter who has a knowledge of the various symptoms of trouble and who is able to eliminate some of these minor troubles himself, being also competent to advise

[1] Superintendent of transportation, Southern California Edison Co., Los Angeles.

mechanics how to eliminate the causes of the troubles found. But an inspector or trouble-shooter is handicapped greatly in his work unless he receives from the driver of the vehicle a report which describes the trouble found, so that he can get the driver's idea of the cause of the trouble. We have found, after years of experience, that the most effective way to communicate this information to the trouble-shooter is to require the drivers to make a written report and, if necessary, to give the inspector such additional verbal information as may be necessary.

A driver often has no knowledge of the mechanism of his vehicle other than how to start and stop it and direct its course, and when trouble develops he may be mistaken as to its cause. Recently, one of our salesmen who drives a Ford car brought it to the garage and reported that it was knocking very hard. When the inspector looked the car over, he asked the driver how long one of its tires had been flat. The driver said he did not know it was flat. After the tire was changed to one properly inflated, the supposed knock in the engine immediately disappeared. But the salesman's inability to determine the cause of the trouble was an additional expense to the company, because a tire had been ruined by being run flat.

Written reports of trouble also serve as a check upon actual work done by mechanics who are supposed to be working upon vehicles in trouble. In many instances drivers intend to report trouble verbally when vehicles are returned to garages, but fail to do so. In some cases the driver claims to have reported to the inspector, and the inspector claims he did not receive the driver's verbal report. The written trouble-report, therefore, is an important document. Our opinion is that trouble reports should be made out for each day's operation. If the vehicle is working satisfactorily, the fact should be so noted by the driver on the report.

Test Procedures

To test for proper compression the engine should be turned over slowly, using the starting-crank. This should be done when the engine is hot, immediately after stopping it. If the tappets are adjusted too close, the expansion of the valve-stem will cause the valve to ride and compression will be lost, this in turn resulting in valve warpage. It has been found that faulty compression is the most frequent reason for a cylinder failing to fire.

An inspector should be trained so that a rough test will indicate to him the proper tram of the wheels and their correct alignment, as well as the condition of the front wheels with reference to steering-knuckle-arm adjustment and loose pins.

Low tire-mileage is one of the largest factors of high operating costs. Rear wheels should be checked occasionally to determine, first, whether the wheels are tight on the axle shafts and, second, whether the wheels are running in true alignment with the frame. Many thousands of miles of tire mileage are lost through lack of this particular inspection.

The driveshaft should be turned by hand to determine the amount of backlash.

Adjusting-bolts on the fan should be carefully inspected. Many radiators are ruined through lack of this inspection.

Inspection of water level in the battery is essential. One of the greatest aids to motor-vehicle operators is the practice of keeping clean, by spraying or other means, the engine unit, the transmission, and the front and rear axles, so that a rapid inspection is possible and so that an opportunity is given to the mechanic to do first-class work at any time. Cleanliness also is conducive to careful handling of equipment. One of the first indications that a man is a good mechanic is that he makes sure the parts have been properly cleaned before he starts to work on a job.

Many arguments can be advanced both for and against a system of periodical inspection, but our experience is that this procedure and the immediate remedying of troubles eliminate expensive overhauling of engines which might, without this, be necessary.

An idea is prevalent among certain operators that motor-vehicle efficiency is greater when a piece of equipment is torn down and completely rebuilt at specific intervals. This may be true when a fleet is composed of various makes of vehicle and it is difficult to predetermine any period of time or mileage after which a vehicle should be overhauled. But our opinion is that careful periodical inspection, in conjunction with reports from drivers, not only tends toward economy in the vehicle's operation but also toward continuity of service and prevention of loss through other channels which cannot be determined until the loss occurs. Greater effort should be made by those responsible for motor-vehicle operation to develop men who are capable of making accurate inspections and, in addition, are competent to advise the mechanical force as to the amount of work necessary to eliminate developed trouble. The cost of maintenance can in many instances be kept to the minimum if correct diagnosis is made at the time of inspection. An inspector also should be trained to determine when it is necessary to retire a vehicle from service, particularly when it affects some expense item other than that of transportation. Inspection, with adequate adjustment of determined trouble, will give to the motor-vehicle owner a very desirable low operating-cost.

Inspection of Tires

Tire cost and compliance with State regulations must be considered in connection with tire inspection. With reference to cost, the manufacturers of motor-vehicle tires have arrived at a definite recommended pressure for their pneumatic tires. These pressures are determined for maximum loads under normal operating conditions. An operator who avails himself of the experience obtained by the manufacturers in their laboratories and who keeps tires inflated to the recommended pressure will profit greatly. But it has been our experience that many vehicles come from the factories equipped with tires too small for the specific work for which they are used and, unless rigidly inspected, such tires will deteriorate rapidly, particularly if the drivers are not called upon to pay for replacements.

Wheel alignment is more important, however, than proper inflation, for the newer types of tire, particularly for balloon tires. But other conditions have arisen, such as shimmying and cupping. Experience has taught us that proper inflation overcomes many of these troubles, and this can be maintained as a result of rigid inspection.

In California, solid-rubber tires are the ones mostly affected by the State regulations. Flat spots are likely to develop on heavy-truck tires, and these are injurious

not only to the highways but also to the vehicle. If no inspection is made and this condition is allowed to continue, the owner is sure to pay for the consequences either in high cost of operation or in numerous police-court fines.

As to proper loads on certain sizes of solid-rubber tire, the manufacturers of tires are continually being asked by owners for replacements due to breakdowns of solid tires which, in practically all instances, are directly traceable to overloading. Suitable inspection to prevent overloading is the remedy.

No doubt exists in the minds of those who are responsible for the operation of fleets of motor-vehicles that inspection by trained men at designated times is one great factor in the satisfactory and economical operation of the fleets. Inspection gives to the owners an insurance policy for the lowest costs with the maximum amount of work accomplished.

Inspection of Motorcoaches

By F. C. PATTON[2]

THE system used by the company represented by the author in maintaining a fleet of 40 double-deck and 46 single-deck motorcoaches is described. Inspection is divided into daily inspection and adjustment, oil and grease inspection each 750 miles, and general inspection each 2250 miles. Details of these inspections are given.

The separate inspection-sheets cover front axle, springs and steering-gear; carbureter and gasoline line; engine and accessories; electrical equipment; brakes and rigging; body and parts; and clutch, transmission and rear axle. As the various units are inspected they are checked off on the inspection sheet. On completion, the sheets are turned over to the shop foreman. The procedure for making minor repairs is outlined.

CAREFUL inspection of motorcoaches is imperative if interruptions to service resulting from road failures are to be prevented. Since the schedule requires that a given number of motorcoaches must operate, the mechanical department must keep that number of units in operating condition continuously and predetermine, so far as possible, the probable mechanical failure of the various units so that needed repairs and replacements can be made before actual failure occurs on the road. It is not my intention to point out the best method of inspection, but merely to describe briefly the system used by our company in maintaining a fleet of 40 double-deck and 46 single-deck motorcoaches.

Our system divides inspection into the three major groups of (*a*) daily inspection and adjustment; (*b*) oil and grease inspection each 750 miles; and (*c*) general inspection each 2250 miles. The daily inspection is based primarily upon information furnished by each driver at the end of his run. He is required to note on the "defect card," which is carried in the vehicle at all times, any defect that comes to his attention. The card is removed at the end of the day and a mechanic is assigned to make the repairs. After the motorcoach has been serviced and placed in line in the garage, an inspection is made for visible defects. In the case of air-brake-equipped units, the brake-shoe liners and brake-drums are inspected very carefully and the brakes are adjusted. Brake-shoe liners that are worn too thin are replaced before the vehicle is sent out.

The night crew makes light repairs only. All heavy repairs are made by the day shift, the motorcoach being placed over a pit. Large units are not repaired while on the coach; the defective part is replaced by a spare part and repairs and rebuilding of the defective unit are done at the bench. The system of unit repairs covers such items as engine, generator, starter, transmission, and differential.

[2] M.S.A.E.—Assistant manager, Los Angeles Motor Coach Co., Los Angeles.

THE PERIODIC INSPECTIONS

Inspection for oil and grease each 750 miles is made at night, the coach being placed over the pit for this purpose. Accurate records of mileage are kept by the mechanical department, and the greaser is furnished daily with a list of coaches which are due for inspection for oil and grease. Careful inspection for defects or failures in the chassis and the under part of the body is also made at this time, the idea being to prevent trouble.

The third and most important inspection is made after each 2250 miles of operation. It should be noted that this occurs at every third oil-and-grease inspection. This general inspection is made during the day, while the coach is over the pit; and the vehicle is gone over carefully from front to rear bumper by the inspection crew. These men are instructed to repair or replace any unit which, in their estimation, will not run without failure until the next general inspection. Special inspection-forms are provided upon which are listed the parts requiring special attention. To simplify the work, the coach is divided into seven major sections, each section containing units of the same general nature. As each section is covered by a separate inspection-sheet, it is possible to have several inspectors working on the same coach without interference with one another.

The inspection-sheets have the following headings: (*a*) front axle, springs and steering-gear; (*b*) carbureter and gasoline line; (*c*) engine and accessories; (*d*) electrical equipment; (e) brakes and rigging; (*f*) body and parts; and (*g*) clutch, transmission and rear axle. As the various units are inspected, they are checked off on the sheet. When inspection is completed, the sheets are turned over to the shop foreman, together with a report of the work that the inspectors were unable to do. The following instructions are printed on the sheets, which are filed for future reference:

Front Axle, Springs and Steering-Gear

(1) Inspect the wheel bearings, spindles and rods. If necessary, jack up the front wheels
(2) Check the front wheels for alignment
(3) Tighten the front-wheel nuts
(4) Inspect the front springs and tighten the clip nuts
(5) Inspect and adjust the steering-gear. See that all joints are free and that grease is reaching all bearings
(6) Inspect the spark and gas-control gears and rods. Make sure that they are all properly connected. Replace all worn ball-joints
(7) Inspect the rear springs and tighten the spring-clip nuts
(8) Inspect the radius-rods and brackets
(9) Examine all universal-joints. See that they hold grease
(10) Inspect the propeller support-bearing. See if it is properly lubricated
(11) Examine the exhaust pipe and the muffler. Tighten the body bolts
(12) Make a rigid examination of the frame for cracks and loose rivets
(13) See that the speedometer is in working condition

Carbureter and Gasoline Line

(1) Clean the carbureter
(2) Examine all gasoline and vacuum lines for leaks
(3) Keep all lines from rubbing other parts
(4) Clean out all lines
(5) Remove the top from the vacuum tank and clean the bottom of the tank. Examine valve and float levers and springs. Assemble, using new gaskets, and test with a vacuum gage; it should read near 16 lb. and hold it. Rigid inspection is necessary to prevent road failure
(6) Examine the gasoline tank for leaks and see that the vent is open. Start the engine; let it heat to about 160 deg. fahr. and then check the carbureter
(7) Be positive there are no gasoline leaks

Engine and Accessories

(1) Check the engine for timings
(2) Check the compression in all cylinders. Use a compression gage if necessary
(3) Clean the spark-plugs and set the spark-gaps
(4) Tighten the cylinder-head nuts
(5) Adjust the valve tappets. Set them while the engine is hot
(6) Make an examination for broken valve-springs or cups
(7) Adjust the oil pressure
(8) Tighten or repack the water-pump. Check the water circulation through the radiator
(9) Adjust the fan belt and grease the fan. Also try the fan for end-play to see if the thrust washer is worn
(10) Inspect the radiator and hose for leaks. Renew if the hose will not last until the next inspection
(11) Tighten the cylinder-base nuts and the oil-pan nuts
(12) Tighten the exhaust-manifold nuts
(13) Clean and adjust the oil-filter
(14) Examine the magneto ground-wires
(15) See that all parts of the engine are clean
(16) Inspect and tighten the timing chain
(17) See that the magneto and the generator shafts line up properly
(18) Inspect the compressor, the belt or chain, and both pulleys or sprockets
(19) Inspect the oil level and clean the glass
(20) See that the pop-valve operates at the proper pressure

Electrical Equipment

(1) Fill the battery with water. Do not over-fill
(2) Clean and scrape the battery posts and terminals
(3) Check the battery with a battery-cell tester. The reading should be not less than 1¾ volts for each cell. Also check the specific gravity of the electrolyte with an hydrometer. The reading should be not less than 1.225.
(4) Examine the cable grounds for looseness
(5) Examine all terminals for corrosion
(6) Oil the generator bearings
(7) Clean the commutator brushes. Make sure that all slide freely in the holder and are not too short
(8) Check the generator output with a voltmeter
(9) Check the starter for grounds, using an electric light for testing
(10) Check the starter load with an ammeter
(11) See that all lamps burn properly
(12) See that all lamps, lenses, brackets and shades are clean, tight, and in good condition
(13) Examine and test the horn
(14) Test all buzzer and bell buttons
(15) Check the light-load at the battery with an ammeter. The load should not be greater than the rated consumption in the circuit
(16) Check the voltage at the lamp sockets. A loss of 1 volt there shows a loose or a poor connection or corrsion
(17) Clean the distributor thoroughly

Brakes and Brake-Rigging

(1) Adjust or re-line the brakes
(2) Inspect the brake-drums
(3) See that all joints are free and not frozen
(4) Remove the rear wheels, replace the brake-drum if badly worn
(5) Replace all cotter-pins that are rusty or loose in the hole
(6) Oil all connections, pins and clevises
(7) Inspect the hand-brake ratchet
(8) Replace the rear wheels. Note that Timken axle bearings should never be pulled tight
(9) Inspect the gages and the air line on units having air-brake equipment
(10) Every movable part must be thoroughly greased
(11) All wheel bearings must be repacked with grease before assembling
(12) Clean out and test all air lines and brake chambers

Body and Parts

(1) Examine and oil all doors
(2) Examine seat brackets and cushions
(3) Replace broken and cracked glass
(4) Test and fill fire extinguishers
(5) Examine deck boards on the upper deck
(6) Examine windshield, hinges and rubber
(7) Examine front and rear bumpers
(8) Examine all fenders
(9) Examine skirts
(10) Examine hood sills and fasteners
(11) Tighten license-plates
(12) Examine roof for leaks
(13) Examine ventilators
(14) Examine upper-deck seats
(15) Examine upper-deck windshield

(16) At each second inspection paint the radiator, shell, hood and front axle
(17) At each fourth inspection paint the fenders
(18) Tighten all upper-deck-railing bolts

CLUTCH, TRANSMISSION AND REAR AXLE

(1) Remove floor-boards and clutch inspection-plate
(2) Examine and adjust the clutch
(3) Oil the pedals
(4) Remove the transmission-case cover
(5) Examine the gears
(6) Try the shaft for loose bearings
(7) If oil is thin, or heavy enough to channel, wash and refill
(8) Inspect the rear axle, the gears and the bearings. If oil is thin, or heavy enough to channel, wash and refill
(9) Tighten the rear-axle-housing bolts. Examine for oil leaks. Replace the gasket if necessary

PROCEDURE FOR MINOR REPAIRS

In addition to the regular inspection already outlined, a carpenter and a painter are kept busy making minor repairs to the bodies, so that the equipment shall be kept in the best possible condition. We also keep a mechanic at the terminus of the double-deck-motor-coach line during the day to make minor adjustments. This practice is to prevent road calls that would require the use of a service car.

The interior of the coaches is dusted and the windows are cleaned daily, and this is supplemented by frequent washing. A high-pressure water system is used for the chassis and the engine. For the outside of the body, a system of pipes is arranged so that water can be played on both sides of the coach at the same time, mud and grease being removed with a long-handled brush. The inside of the coach is washed with a hose, and the windows are cleaned with a special window-polish.

Tire inspection is kept entirely separate from the inspection of other units. The 36 x 6-in. tires are checked for inflation pressure every 48 hr., and the 36 x 8-in. tires are checked every 24 hr. At the time the air pressure is checked, the tire is also inspected for excessive wear. Wheel alignment is tested once each week with a wheel-alignment device. Records of tire mileage are kept in such a way that the number of miles a tire runs on each wheel can be determined easily and its performance analyzed.

The mechanical department furnishes the operating department with a daily list of coaches available for runs as well as those held for inspection. As the primary reason for inspection is to prevent road failure and delay, the dispatcher is required to keep a record of all trouble calls, together with the reason for the call and the number of minutes of each delay. This information is summarized daily on a special report, to which is added the date of the last 2250-mile inspection.

Maintaining Motor-Truck Axles

By C. H. JACOBSON[3]

FRONT and rear axles of any motor-vehicle should receive careful inspection and maintenance because they receive the driving strains and road shocks, and this inspection should be made by a thoroughly competent mechanic who knows where to look and what to look for when making an inspection. He should be supplied, according to the author, with guide charts and report forms to assist him in his inspection and for use in making his reports accurate and comprehensive.

Details of front-axle inspection are discussed and the recommendation is made that such inspection should occur at the end of every 5000 miles of operation. The inspection includes the steering-system. At the end of every 50,000 miles the complete front axle should be removed, dismantled and overhauled. An analysis is made also of worm-drive rear-axle inspection, which should be made after each 5000 miles.

In conclusion, the author outlines proper lubrication methods and says that it is better to use oil and grease in small quantities at frequent intervals than in large quantities only occasionally. He states that too many operators think they lubricate their equipment thoroughly, when, in fact, the oil channels are so badly choked with dirt and caked grease that the lubricant never reaches the wearing surfaces.

INSPECTION of a motor-vehicle for maintenance purposes is made to ascertain whether the various units require immediate replacement or repair and how long the units will operate before a failure may occur. To make the proper examination and analysis of the condition of the axles, the inspector should be thoroughly familiar with the details of their design. The front and rear axles of any motor-vehicle receive the driving strains and road shocks; therefore they should be given careful inspection and maintenance to keep them in first-class condition.

Inspection should be performed by a thoroughly competent mechanic who knows where to look and what to look for when making an inspection. This will make it certain that defective parts are taken care of at the proper times and will help to maintain efficiency and to eliminate the possibility of untimely break-downs. Even though the inspector is very competent, it is wise to supply him with charts and report forms to guide him and on which he can make reports. By referring to these inspection charts and reports, the master mechanic or superintendent can decide quickly whether a certain service operation has been required too frequently and can eliminate any excessive expense.

FRONT-AXLE INSPECTION

The front axle should be inspected at the end of every 5000 miles of operation. First, the inspector should look at the inner side of the front wheels, close to the hub, to see if there is any sign of grease leakage.

[3] M.S.A.E.—Service manager, Moreland Motor Truck Co., Los Angeles.

Next, the front wheels should be removed and the hubs and bearings washed thoroughly with gasoline or kerosene. If an oil leak has been noticed, the oil seals should be examined for wear, looseness, or any other condition that may have caused the leak. The inspector should make certain that the surfaces are smooth and are not cutting the oil-seal material. He also should inspect the hubs to ascertain that there are no signs of failure or cracking, and that the bearing cups are properly seated and are not loose in the hubs. He should be sure that the bearing cups have not become worn or pitted to such an extent that failure may occur before the next inspection.

The steering-knuckle should be thoroughly checked to see that the bearing fits properly and that no grooves are being cut in it because of improper lubrication or any other cause. Grooves or cuts of any kind will localize strains and may cause the part to break in operation. The steering-knuckle pivots should be checked for looseness. The oil-grooves, through which the lubricant feeds to the operating surfaces, should be inspected to make certain that they are not clogged.

The steering connections and the steering-knuckle tie-rod should be thoroughly checked for looseness, for leakage of lubricant, and for facilities for lubrication. When inspecting the steering connections, the inspector should make certain that all locking devices such as cotter-pins are securely in place. He should be certain that cotter-pins have been properly spread and that the complete cotter-pin has been installed. In many instances a mechanic will remove such a part in service work and, in replacing it, because the cotter-pin holes do not line up accurately, the pin is split and only half of the pin is assembled in place. This is an extremely bad practice and should not be tolerated.

If the spring clips are not tight they should be tightened up very thoroughly. The toe-in of the front axle should be inspected and adjusted to its proper setting as determined by operating conditions; also, the camber of the wheels should be checked. After dismantling and inspecting the front axle, the parts should be carefully reassembled and properly locked in place by the devices provided for this purpose.

At the end of every 50,000 miles the complete front axle should be removed and entirely dismantled, every part being removed from the unit and given a thorough inspection. When defective or worn parts are replaced with new ones and the axle is reassembled and repainted, it is virtually the equal of a new axle.

Worm-Drive Rear-Axle Inspection

After each 5000 miles of operation the following inspections should be made. In inspecting a truck rear-axle of the full-floating type, the inspection should be essentially the same as that described for the front-axle hubs; that is, the hubs should be carefully inspected for cup looseness and the like, and the oil-seal parts should be checked. In inspecting the semi-floating or fixed-hub type of rear axle, the keyway of the hub which is keyed to the axle-shaft should be checked as to its fit. If it is loose on the axle shaft, if the key does not fit the axle shaft and hub properly, or if any of the parts have become worn to such an extent that a new key will not fit the keyway properly, the worn parts should be replaced. The keyway can be enlarged and a new key assembled to fit the axle shaft and hub, but such practice should not be encouraged, as it is better to standardize so that it will not be necessary to carry in stock several sizes of the same part.

After the wheels have been removed, the brake-drums should be inspected for both wear and tightness on the wheels. The drum should be checked with an indicator to prove its concentricity with the hub. It may be discovered that the hub bolts holding the drum to the wheel have loosened, allowing the drum to shift. This should be corrected, in which case it may be necessary to replace the drum or to refinish its braking surface. This should be done after the drum is mounted on the wheel. The surface of the inside or brake diameter should be turned true with the hub bearing so that the drum runs true within 0.001 in.

The brake-shoes should be inspected for proper brake-lining condition, the inspector making sure that the lining has not worn down below the rivets; otherwise, the rivets will cut the drum. He also should make sure that the lining is not soaked with oil and that it has not become glazed. The face of the cams which operate the brake-shoes should be inspected for wear caused by the operating cams. If wear has occurred to such an extent that it affects the operation of the brakes, the face of the shoe against which the cam operates should be machined. A steel plate should be placed on the brake-shoe face or the shoe replaced with a new one. The bushings holding the camshaft in place should be checked for proper lubrication and for wear, the inspector making certain that the lubricant can reach the operating surface. The brake-shoe pins or other anchor points also should be inspected for wear and lubrication possibilities. In some cases the movement of these pins is so slight that lubrication is unnecessary.

Inspect the worm-shaft bearings for end-play, and if more than the needed amount exists remove the bearings from the carrier to determine just what has caused this condition. If the excessive end-play is not corrected, the pounding of the bearings back and forth may result in their destruction, which might necessitate a very expensive repair job. Inspect all the oil-seal parts in the carrier assembly. If any oil is leaking, the stuffing box should be tightened or repacked with new packing.

The axle housing should be examined carefully. The inspector should see that the bolts which hold the differential-carrier assembly in the axle housing are tight and make certain that the spring clips are tight. He should check all other bolted parts to assure himself that they fit and are tight enough to withstand the severe strains usually imposed on a truck rear-axle.

The operations described are more or less routine and are intended to determine whether any repair work is necessary on the external parts of the rear axle.

Rear-Axle Work After 50,000 Miles

After each 50,000 miles of operation the entire rear axle should be removed from the truck and the differential-carrier assembly removed from the housing and checked thoroughly. To do this, it is necessary to take out the axle shafts, which should be inspected thoroughly at this time. The carrier assembly or driving unit should then be thoroughly washed with gasoline or kerosene so that wear that has taken place can be seen. The worm should be carefully inspected for wear. The proper bearing or contact between the worm and the worm-wheel should be checked. This contact should not shift from its factory setting unless unusual wear has

occurred at the differential bearing. If the worm-wheel shows excessive wear on the driving side and not on the coasting side, on some axles it can be reversed so that the coasting side will become the driving side.

If it is decided not to reverse the worm-wheel, an inspection should be made of the differential bearing. This is done by removing the differential side-bearing cups and examining them for wear and other conditions which will interfere with their operation. Also see that the differential gears are not chipped or broken, and that too much side-play does not exist between the side gears and the differential case. Too much play or wear at this point may allow the differential side-gears to come out of mesh with the differential pinions to such an extent that the teeth will be bearing only on their points, and failure or chipping will result. Such a failure may destroy the differential, and the broken parts may reach the other working parts of the axle and result in ruining the entire unit. This play can be remedied either by replacing the differential case or by machining it so that a bronze thrust-washer can be assembled between the case and the gear. All cases that are machined should be held to definite dimensions, so that the same size or thickness of washer can be used in all repair jobs of this kind.

If the worm-wheel shows unusual wear and has developed any sharp or rough edges, use an ordinary bearing scraper to round off or remove these edges. The wheel will then be capable of running another 50,000 miles in service. Likewise, if the worm-shaft is worn or shows any rough surfaces, it can be polished so that these surfaces are smooth and the operation of the worm with the worm-wheel will not cause any cutting. Also inspect the keyway of the worm-shaft to make sure that it is of proper size and will not cause any trouble from looseness.

The only inspection that need be made on the carrier casting itself is to see that the bearing cups fit properly in their respective seats and do not turn in their housings when assembled. See that the oil-channels and oil-holes leading to these bearings are cleaned out thoroughly, so that the oil will flow freely to the bearings. All threads, such as in the differential adjusting-nut, should be thoroughly cleaned out and inspected to see that they are not cross-threaded or burred. The nuts should assemble and work easily.

In reassembling the parts, make sure that the threads and their respective parts fit properly; they should not be loose enough to allow end-play, and not tight enough to make a faulty adjustment possible. A tight thread often deceives a mechanic when he is adjusting a mechanical part.

See that all locking devices are properly assembled and thoroughly locked in place. After the assembly is complete, check the worm-wheel and all its bearing adjustments with an indicator. Do not guess at an adjustment; be accurate. Check the end-play of the worm-shaft with an indicator, and keep to the prescribed limits.

In riveting a worm-wheel to a differential, it is best to cold-rivet; but in many cases this cannot be done because expensive equipment is required for cold-riveting. When hot rivets are used, do not heat them too much and be certain to drive them in so that when they cool and shrink there will not be enough looseness to cause trouble. Carefully reamed holes and carefully sized bolts may be used in place of rivets in case of replacement.

Careful practice of the principles laid down herein will result in a big reduction in maintenance costs.

Lubrication Practice

Bear in mind constantly that proper lubrication at all friction points is of primary importance, and that it is better to use oil and grease in small quantities at frequent intervals than in large quantities only occasionally. If lubrication is neglected the necessity for adjustments and replacements will increase in direct proportion to the lack of proper lubrication. Even the highest-priced lubricant is vastly cheaper than labor and parts, and the cost of lubrication represents only a very small percentage of the total operating-cost. Only lubricants of the highest grade should be purchased, and their correct and conscientious application should be watched carefully by the head of the mechanical department, as this is clearly the most important means of keeping maintenance costs low.

Oil is one of the most difficult things in the business to purchase, as there are no definite standards by which it can be gaged by the layman. Buying oil on specifications does not mean a great deal, as several oils with totally different lubricating qualities may show the same flash, fire, viscosity and specific-gravity values. Therefore it is safest to purchase lubricants from a reliable firm of excellent standing in the industry, and to accept the recommendations of that firm's engineers as to the grade and type of lubricant best suited for the specific needs.

Competent mechanics realize the importance of proper lubrication, but lubricating usually is left to an inexperienced mechanic or oiler. Workers of this class may ignorantly neglect this very important phase of maintenance. Charts or guides should be devised to instruct the oiler to oil or grease certain operating points at the end of a specified number of miles. The oiler should be trained to see that the grease or oil gets to its proper destination; not merely that it is started through a lubricating fitting. Often it fails to reach its destination because the lubricating trough is clogged and the lubricant oozes out between openings. Too many operators think they lubricate their equipment thoroughly, when, in fact, the oil channels are so badly choked with dirt and caked grease that the lubricant never reaches the wearing surfaces.

Inspection for Overhaul and Repairs

By JAMES L. FERGUSON[4]

AFTER emphasizing the importance of finding out directly from a patron the kind of trouble he is having and getting the patron's viewpoint, the author outlines the proper subsequent procedure for the maintenance and repair of the better grades of passenger-car. Concerning the actual diagnosis of trouble, he says that the best way to determine what may be wrong is to drive the car as nearly as possible under the same conditions as to speed and road as those under which the patron finds the trouble present. If the job is evidently a difficult one, only an experienced man should be permitted to diagnose the trouble.

Assuming that a car has a sharp knock or loud click whether the engine is running fast or slow, and that the noise is present regardless of whether the car is in motion or not, the author analyzes the problem of locating the trouble quickly without dismantling the car. In general, the statements apply especially to what may be regarded as special or unusual maintenance and repair work that requires more than ordinary intelligence and ability.

MAINTENANCE and repairs on the better grades of passenger-car require inspection methods for diagnosing complaints and accepting repair work that are perhaps less methodical than might otherwise be demanded, since the procedure must often be varied to suit the particular problem as well as the customer. The one important thing that must be done upon meeting a customer is to find out first from him what trouble he thinks he is having and to get his viewpoint of the situation. At this time one must beware of hasty judgment. Customers do not like to be told what work they should have done before they have an opportunity to state their case or, as they say, "before I get my car stopped on the floor of your service station." Neither do they place any confidence in snap judgment. It is far better, if the cause of trouble is not plainly evident, to tell a customer that it will be necessary to make an inspection or a road test than it is to guess at the trouble. The problem therefore includes psychological analysis of the customer, especially if he is a new patron whose confidence has not yet been secured.

Some patrons immediately request that a service man take a ride with them to determine what is wrong with the car. Others will state what is wrong or what should be done to the car. Every detail of the customer's complaint about the condition of his car should be considered courteously and patiently, with the one idea of learning in just what respect the vehicle is not operating satisfactorily. It is therefore evident that the patron's order must be recorded intelligently, as experience shows that most of the come-back complaints are due to incomplete orders resulting from paying insufficient attention to each detail of the patron's trouble as he states it.

Concerning the actual diagnosis of trouble, the best way to determine what may be wrong is to drive the car as nearly as possible under the same conditions as to speed and road as those under which the patron finds the trouble present. Sometimes it is necessary to have the customer drive the car, and this may prove that the cause of his complaint is his improper operation of the car in some small detail.

If the job is evidently a difficult one, only an experienced man should be permitted to diagnose the trouble. Even then it sometimes becomes necessary for him to consult with others before proceeding to dismantle a car, and occasionally a car comes in that baffles every attempt at locating definitely the cause of noise.

LOCATING THE CAUSE OF A KNOCK

Let us suppose that a car has a sharp knock or loud click whether the engine is running fast or slow, a noise that is present all the time regardless of whether the car is in motion or not. The problem is to locate the trouble quickly and always, if possible, without dismantling. If the noise is present while the car is standing on the floor with the engine running, it must be in the engine. Here the principle of the stethoscope can be utilized, locating the noise by holding a common long screw-driver against various parts and listening while the ear is held against its handle until the exact location of the noise is determined. The trouble may be found to be a valve-lifter noise caused by a slight excess of clearance between the lifter and the end of the valve-stem, which is readily eliminated by readjusting the valve-lifter tappet. Ordinarily, this particular noise is readily detected by an experienced ear.

If the knock is a sharp one, heard only when the car is running and the engine pulling hard or picking up speed in high gear, the question is whether it is in the engine or not. A ride in the car indicates, we will say, that it is in front of the driver's seat; that it comes at a speed of about 20 m.p.h. or at a certain engine speed that can be ascertained by observing the oil pressure or the ammeter reading. An experienced ear may detect a loose piston, but it is necessary to find in which cylinder the noise is. If it cannot be located on the road by the stethoscope method, the rear of the car can be placed on a stand to get the wheels off the floor, the engine started and operated at the same speed in high gear with the brakes partly applied. Better yet, if a testing machine or dynamometer is available so that the engine can be made to pull a load without having the brakes applied, each cylinder can be tested by different methods. The firing of a cylinder can be eliminated by grounding the spark-plug of one cylinder at a time, thereby relieving the pressure, or a device can be used that injects a quantity of lubricating oil into the suspected cylinder while the engine is running, which very effectively cushions the piston and usually stops the noise.

Again, the knock may be heard only when the car is running in intermediate gear, in which case it can be located by letting the car coast slowly in that gear, with the engine dead. If the noise is then present, the

[4] A.S.A.E.—Superintendent of service, mechanical department, William E. Bush, Inc., Los Angeles.

indication is a damaged gear tooth on one of the transmission gears, or a sprung transmission-countershaft, and its exact cause can then be determined.

If the knock is at the rear of the car, in either low, intermediate or high gear, or when the car is coasting with the gearshift lever in neutral position, but an inspection and test shows that it has disappeared when the rear of the car is placed on a stand, it then becomes necessary to remove the rear cushion and the panel underneath it and either to place the car on the test stand again or run it on the road. Then the stethoscope method must be used to determine whether the noise is louder near the bevel-pinion-shaft housing or at one of the rear wheels. A broken or defective bearing may be found at either place.

Source of Trouble Found by Elimination

Often, patrons complain that "something is broken" or of "too much backlash in the rear axle"; but, after testing, it frequently is found that the engine is misfiring in one cylinder and, when the patron is so informed, he does not want to believe it. It sometimes happens that an owner has just finished cleaning and readjusting the spark-plugs and either has left off one of the spark-plug wires or has adjusted one of the spark-plugs improperly.

The process of elimination is used very effectively at times while locating trouble. For example, when locating a squeal or noise which may be caused by a dry bearing in the fan, the generator, the ignition unit, the water-pump, or even in the oil-pump, if the suspected unit is made inoperative or is replaced, the noise either disappears or indicates by its persistence what the next procedure should be.

All the foregoing remarks apply especially to what may be regarded as special or unusual work. The general work of overhauling is usually much easier to handle. As a rule, an owner who takes an interest in his car comes to know by watching its operation and by consulting from time to time with the service men what the cause of trouble is likely to be. When such an owner needs work done, he has a very definite idea of what is necessary and what the expense will be. Under such circumstances the diagnosis of a job is not difficult. When this is not true the situation can nearly always be handled successfully, after driving the car, by an experienced service salesman who has tact and good selling ability. The rule to follow is to be sure you are right and then go ahead. A proper diagnosis is the basis of a satisfactory and profitable transaction, but a wrong diagnosis creates dissatisfaction and is an expensive mistake.

THE DISCUSSION

WILLIAM M. BRITTON[5]:—The correcting of steering-knuckle arms is one feature of front-axle inspection which often is neglected and may be the cause of difficult steering and excessive tire-wear. The usual remedy is to readjust the tie-rod so as to produce proper toe-in, if any is used, at least to procure proper alignment; and mechanics believe they have finished the job when they have obtained proper alignment. These arms are still bent, and every time the vehicle turns a corner one tire or the other is dragged around the turn. The proper position for the steering-knuckle pivot and the tie-rod pin is in a direct line to the center of the rear axle, for the average passenger-car wheelbase, but many mechanics do not know this and simply adjust the length of the tie-rod.

What is the best routine method of determining the exact position of the pivots of the tie-rod to prevent the foregoing difficulty?

PAUL HINKLEY[6]:—We determine the proper setting of the steering-knuckle arm by measuring from the center of the tie-rod pin to the center of a spoke in the front wheel, since we know what this distance is when the vehicle leaves the factory and take it for granted that it has been properly engineered as to design. In adjusting for toe-in, if an arm is bent enough to require more than the equivalent of one turn or one thread on the tie-rod to correct the trouble, the arm is renewed. It is common practice with some concerns to attempt to bend the arm back to its original position; but, to do this, it usually is necessary to heat it, which is bad practice. In most instances it is cheaper to renew the part than to try to recover the old part. We recommend renewal.

ETHELBERT FAVARY[7]:—That is an important point. So often, with a bent part, we think if we heat and straighten it we have remedied it. But all those parts are heat-treated and, when such a part is heated, that portion of the assembly is weakened about 50 per cent. Therefore, when a part is bent to such an extent that it cannot be straightened cold, it is much better and cheaper to replace it with a new one. That applies also to a number of the stamped brackets made of cold-rolled steel, which has a tensile-strength of about 65,000 lb. per sq. in. When it is heated it becomes annealed and the strength is reduced to about 30,000 lb. per sq. in. Hence, the argument applies to both heat-treated and cold-rolled steel parts.

W. B. CANNON[8]:—In connection with the geometry of the steering-gear, should the prolongation of the center line between the steering-knuckle pivot and the tie-rod pin meet in the center of the rear axle?

MR. FAVARY:—No. The steering-gear layout is determined mathematically and it depends on various factors, including the length of the wheelbase.

CLARENCE V. ELLIOTT[9]:—What material does Mr. Patton use for brake-drums and brake-shoes?

FRED C. PATTON:—With the all-metal brake, we are using a brake-drum having approximately 0.45 per cent carbon and, for the brake-shoe liner, plow steel having between 0.20 and 0.25 per cent carbon.

WILLIAM H. FAIRBANKS[10]:—What are the averages of motorcoach breakdowns due to mechanical failures and to tire failures?

MR. PATTON:—Our time lost on an average aggregate mileage of about 6000 miles per day for say 90 vehicles

[5] M.S.A.E.—Manufacturer's representative, consulting engineer, Los Angeles.

[6] Engineering department, Walter M. Murphy Co., Los Angeles.

[7] M.S.A.E.—Consulting engineer, manager sales promotion, Moreland Motor Truck Co., Los Angeles.

[8] Superintendent of equipment, Department of Public Works, division of highways, State of California, North Hollywood, Cal.

[9] M.S.A.E.—Engineer, Hughes Tool Co., Los Angeles.

[10] M.S.A.E.—Supervisor of shops and vehicles, Southern California Telephone Co., Los Angeles.

is less than $1\frac{1}{2}$ hr. per day. But the fact that we have to send a service car out in the tire failures often causes a delay. We replace the vehicle rather than hold it up. That applies particularly to the small lines where only one or two units are in service. On the two larger lines we limit the drivers to about 5 min. to fix trouble so as not to lap a headway. If trouble causes delay that will lap a headway, we replace the vehicle. That increases replacements but decreases lost time.

Our road calls average 10 to 15 per day on the 6000 miles. Some troubles require a replacement and some do not. With the dual rear-wheels it is impossible to change a tire on the road without losing too much time, and we replace the equipment. That entails also the transferring of passengers. We sometimes operate the vehicles until 4 p.m. without having a call for road servicing.

What suits one driver may not suit another. When another driver takes the vehicle he usually wants some change made. So long as the one driver has the vehicle, we are not so likely to be called upon for road servicing. In the middle of the day we operate less than 50 per cent of the equipment that we operate at night, which causes us to split our runs. A man works in the morning, takes time off, and goes back in the afternoon. When three or four men operate the same vehicle, at least one of them will find something wrong; but one driver would have run it all day without calling for service.

C. MAYNARD PARSONS[11]:—We use a monthly inspection-system, having all the equipment brought into the service station at least once a month. The system includes complete oiling and greasing, and repairing of necessary parts, at a fixed price. It has proved to be very successful. The car of an owner who patronizes the inspection system is in better condition than is the car of one who does not. We keep a list of all the mechanical trouble with the car, and whether or not it was corrected. A space for suggested work is provided on the record form. That feature has worked out very successfully.

H. E. CLEMENS[12]:—Regarding breakdowns on the road, we have 160 vehicles in service, operating a total of about 500,000 miles per month. The monthly average delay for breakdowns is about 8 hr., including the time the operator waits for the repair man. Usually the service car reaches the disabled vehicle in 15 min.

GARFIELD D. GENERAUX[13]:—We lubricate trucks after every 500 miles of operation, and touring cars after every 1000 miles. We keep an individual-vehicle record of when oil and grease in the transmission and differential are changed, which is after every 5000 miles of operation. We change grease while it is warm, immediately after the vehicles come in from the road. We drain the oil and thoroughly wash out the oil containers with kerosene. As a result, we have several heavy-duty 5-ton trucks, some of which pull trailers, which have operated from 90,000 to 100,000 miles without having transmission or rear-end trouble.

C. S. SWANEY[14]:—My experience in maintaining a fleet of 45 trucks, which are about 6 years old, is that breakdowns average approximately two or three per month, none of them being of a serious nature.

EARL M. FITZ[15]:—We inspect each vehicle at regular predetermined periods. Full cooperation from the truck drivers is necessary, because the abuse of equipment is responsible for many unnecessary repairs.

AIDS TO EFFECTIVE OPERATION

EUGENE POWER[16]:—Someone has said that the three cardinal points of economical fleet operation are selection, inspection and lubrication. Selection is comparatively easy, owing to the excellence of all types of motor equipment now on the market. Of the other two, inspection is more important, because lubrication will follow a correct inspection. The average distance of one of our vehicles from a repair station is about 30 miles, but in one instance our trucks are 700 miles from the shop at which they are overhauled. Our inspectors make all running repairs; major repair-work comes into the central shops. Our aim is to spread the period between overhauls as much as possible.

As to trouble resulting from using different drivers on the same truck, we try to make our traveling mechanics, as we call our inspectors, instructors as well as mechanics. They do educational work among the drivers. A driver assigned to a certain truck takes pride in the vehicle; but, when the drivers are changed, the problem of getting cooperation becomes difficult. We try to persuade our traveling mechanics to utilize their spare time in a missionary capacity.

One difficulty that fleet operators have is due to the fact that operators of the trucks and cars are not financially interested in them. When some other person is to pay the bill, the incentive for a driver to be economical is lessened. Where possible, we believe it is advantageous to group trucks and cars of a similar make in the same district, because the drivers, the shop mechanics, and the traveling mechanics are then conversant with that particular type. It is particularly helpful to the traveling mechanics, who become "wised-up" on complaints to such an extent that they can detect trouble causes more quickly.

GEORGE L. MOSKOVICS[17]:—I have studied service for many years, from both the factory angle and the sales angle. About half of the service difficulty lies with the service man. While I do not claim that he should be a psychoanalyst, he should be a good reader of character. It is a psychological matter to get an irate owner or driver smoothed down so that he can tell a correct story of what his trouble is. The average driver does not know much about automotive equipment. The more ignorant he is the more positive he is, and it requires tact and knowledge of human nature to handle such a situation.

W. C. BROWN[18]:—On inspection, is it wise or profitable to have the man who inspects a vehicle make the inspection and be entirely free from doing mechanical work, reporting to the mechanic who is to do the work? In that way, the man who does the work will not slight anything.

MR. FAIRBANKS:—We tried that, but it caused a jam

[11] Jun. S.A.E.—Pacific Coast service representative, Franklin Automobile Co., Syracuse, N. Y.

[12] M.S.A.E.—General superintendent, Motor Transit Co., Los Angeles.

[13] A.S.A.E.—Superintendent, automotive repair shops, Gilmore Oil Co., Los Angeles.

[14] Regional mechanic, Standard Oil Co. of California, Alhambra, Cal.

[15] A.S.A.E.—Assistant automotive superintendent, Shell Co. of California, Los Angeles.

[16] M.S.A.E.—Manager, properties, facilities, Union Oil Co. of California, Los Angeles.

[17] M.S.A.E.—Sales manager, Pelton Motor Co., Los Angeles.

[18] Superintendent, motor-vehicle service, Post Office Department, Los Angeles.

all the time. Besides that, the expense was duplicated. Our organization does not believe in non-productive inspection. It is the duty of the shop foreman to see that work is not slighted.

BRAKE SAFETY CODE AND HEAD-LAMPS

COKER F. CLARKSON[10]:—Engineers should not be blamed entirely for inadequacy of brake equipment. In all our work we should be somewhat careful to avoid putting the engineer into a position in which he is expected to solve a problem that he does not really control. The kind of brakes installed on equipment depends on the company policy and the cost of the equipment the engineer may recommend. We know that the engineer does not always control the company's policy. At the same time, engineers do not know all about brakes. There has been a steady improvement in the components which make up brake equipment, and a large amount of testing of brake-linings at the Bureau of Standards and in other places. While I think there is no concensus of the best qualified men as to best methods, I believe there has been steady progress along the line.

The Society does not intend to foster any unnecessary regulations with regard to motor-vehicles or anything else; but, so far as possible, it desires to bring out the facts, to have policies defined, and to make the engineering possibilities well understood. When the work was started to formulate the Safety Code for Brakes and Brake Testing, the officers of the Society said that the problem involved was one of policy rather than engineering. A good engineer knows approximately how quickly a vehicle can be stopped. It is a matter of policy as to what the ordinances and statutes should require. That Code has come through; it provides stopping distances for passenger-cars and trucks from certain speeds. Certain provisions are to be in effect only temporarily, it being expected that the variout ordinances will require more provisions, according to reason, as time goes on. The Code is nothing more than the draft of what any uniform motor-vehicle law might be. It is not a law until it goes into effect through some legislature. When it does go into effect, if it is a good law, we know there is a strong tendency for such a law to be followed.

With regard to head-lamps, adjusting the present equipment as well and as promptly as possible is very desirable. We know, however, that the present regulations are not ideal. A good driving-light is bound to cause glare under certain conditions. It has occurred to some men that the whole scheme of head-lamp illumination might be modified by using say an illumination pattern of irregular form. If we had right-hand driving, as formerly, the drivers of the vehicles would not be bothered so much with glare. It is the left head-lamp that is annoying. In all probability we are not going back to right-hand driving. With conditions as they are, the pedestrian would be in trouble even with right-hand driving. One suggestion is that the left head-lamp alone be dimmed. The Society is having some tests made at the Bureau of Standards to try out that and other similar ideas, and the work looks promising.

[10] M.S.A.E.—Secretary and general manager, Society of Automotive Engineers, Inc., New York City.

Reduced Rates on Air Mail

IT now costs only one-quarter as much as formerly to send the average business or social letter by air mail because on Aug. 1 the rate was reduced from 10 cents per ½ oz. to 5 cents for the first ounce or fraction and 10 cents for each succeeding ounce or fraction. This means that an ordinary letter may be sent anywhere in this Country for 5 cents and that an air-mail package which formerly required $2 postage may now be sent to any part of the Country for $1.05.

This new low rate holds out tremendous possibilities for the American business-man. The reduction comes when the air-mail companies are giving the most dependable service in their history. The man or woman using air mail for business or social correspondence has the benefit of 28 air-mail routes over 12,457 miles, serving 62,000,000 people directly and millions more indirectly. Each 24 hr. the mail planes fly 20,000 miles, and their daily average mail-load now exceeds 3 tons. Air mail averages more than 100 m.p.h.; and the airplanes are flown night and day.

Speed is the essence of air-mail service, and the record of efficiency established by the air mail in the last 10 years, during which time nearly 16,000,000 miles were flown and 302,000,000 letters carried, merits much greater patronage of the service. Every alert business-man should determine definitely how time and money can be saved by use of the air mail.

The regulations on air mail are simple. Any mailable matter, except perishable matter liable to damage by freezing, may be sent by air mail. Registered, insured and C.O.D. matter is carried by air mail, as are packages not exceeding 50 lb. in weight and not exceeding 84 in. in length and girth combined. Special-delivery stamps still further expedite delivery of domestic air mail.

Air mail may be deposited in any mail box. Distinctive air-mail envelopes are desirable, but not compulsory, but the words "Air Mail" or "Via Air Mail" must be clearly endorsed on the envelope or wrapper.—Arthur C. Linder, postmaster at Chicago.

Ground Gears and Transmission Design

By H. F. L. Orcutt[1]

Semi-Annual Meeting Paper — *Illustrated with* Drawings

GROUND teeth for transmission gears are advocated because they can be made to the same degree of accuracy as the other fine working-parts of a motor-car.

The designing engineer is held responsible for conditions unfavorable to the adoption of gear grinding by the production department. Mr. Orcutt believes that cluster gears should be avoided because it is impossible to finish them accurately.

Fundamental principles of rigid shafts and correct bearing arrangements are laid down, and the degree of accuracy is specified for the fitting parts. Transmission-case design still needs development and study to avoid resonance.

Designs are recommended that will provide ample center distance to avoid pinions with a small number of teeth. The unmodified involute is recommended as the most satisfactory form of tooth.

Spigot bearings receive special consideration. Two designs of transmission are submitted, in one of which the spigot bearing is eliminated. Simplification is sought by reducing the number of gear sizes used. Four-speed transmissions require gears with only four different numbers of teeth.

Prominent engineers discussed, at the meeting, many of the points in the paper, explaining that their different opinions were caused largely by the difference between conditions in England and in America. Good cut-gears, even cluster gears forged and heat-treated by the best available methods, are said to be as accurate and satisfactory as other parts of the transmission.

American methods of design, based on maximum capacity in pounds-feet per dollar of cost, are described.

Among other points considered are the relative merits of form-grinding and generating-grinding methods; and lubrication, noise and efficiency.

THE spur gear with straight ground teeth can be made more accurate than any other gear and is essential to high quality in transmissions. Its successful use in any transmission system depends principally on two conditions: It must be designed so that it can be produced cheaply, and it must be mounted to give accurate and permanent alignment. In this paper it is proposed to consider in detail these two conditions.

It would be difficult to conceive the motor-car of today, with its refinements, reliability and low cost, without the perfection of its mechanical details such as the crankshaft, pistons, cylinders, camshaft, valves and ball and roller-bearings.

[1] F. M. S. A. E.—Managing director of The Gear Grinding Co., Ltd., Birmingham, England.

Accurate machine-work on these parts is not only necessary to good running, it is essential to progress in design. Without it, tests are misleading and research has no foundation.

The transmission is the only unit of the modern car in which design and production are not in accord with a high degree of mechanical perfection. Fundamental progress in transmission design is impossible when ordinary cut and hardened gears are employed. Substantial and probably unforeseen progress will be made in transmission systems when it is realized that gears themselves now can be finished so that they will run practically silently, and that every pair can be guaranteed to be of a uniform degree of silence.

The quiet-running transmission has, or should have, a

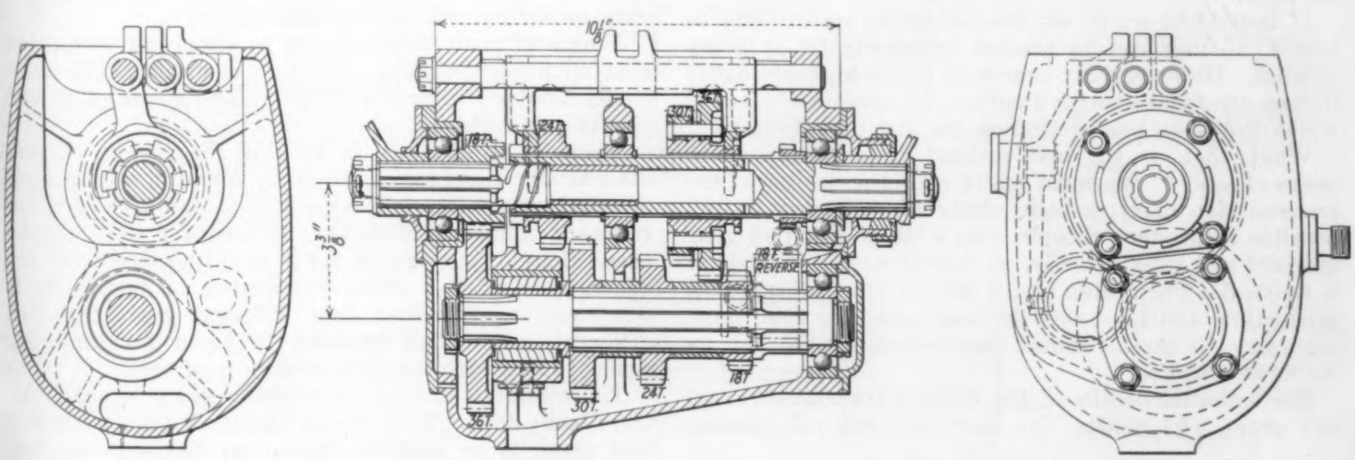


Fig. 1—Four-Speed Transmission for a Small Car

A Design Suggested for an Engine Giving a Maximum Torque of 1100 In.-Lb. All Gears Are 8 Pitch, ⅝-In. Face, 20-Deg. Pressure Angle, with Full-Height Teeth and Ground Profiles. With Only Four Numbers of Teeth, the Ratios Are 1.0 to 1, 1.6 to 1, 2.5 to 1. 4.0 to 1, and 4.0 to 1

greater number of extremely accurate surfaces than any other unit in the car. In the usual four-speed unit there are, on an average, 250 gear-teeth. To give the best results with tooth pressure in either direction, all these 250 teeth must have their 500 separate surfaces accurate within 0.0003 in. These 500 surfaces are complex mathematical curves and should be spaced by the indexing mechanism with errors not exceeding 0.0001 in.

Gear-tooth-grinding machinery and methods are now available that will successfully meet these exacting requirements. Cooperation of the designer and producer is now needed to bring the high-class transmission gear within reach for even the cheapest car.

Universal use of the ground gear is within sight. The designer of transmissions is largely responsible for its slow progress. The production engineer is more or less helpless until the designer alters details so that the high-class silent-running gear can be produced cheaply. Obviously, to avoid prohibitive costs, production must be carefully considered.

Broadly speaking, there are now three distinct routines made use of in gear production:

(1) The hole of the gear is finish-ground, chucking from the finished tooth
(2) Teeth are finish-cut after heat-treating, the gear being mounted on a mandrel
(3) The heat-treated teeth are finish-ground, the gear being mounted on a mandrel

The Best Gears Are Made Singly

First, the designer must decide the quality he wishes in the finished gear, and the best productive routine fashions details accordingly. Noisy running and the greatest irregularity will be found in the so-called cluster gear. It is a hopeless design if high quality is desired. Even with only two gears in the cluster, one or the other or both will be bad; no method of production will make them good. If they are hardened and the hole is ground by chucking from one gear, the other gears will be out of true. The more gears there are on the cluster, the worse are the results. If the teeth are heat-treated and finished afterward, the cutters wear so rapidly that accuracy is impracticable. The cheapest tooth-grinding is impossible on nearly all cluster gears. From the forging to the finished article, cluster gears are a disappointment unless indifferent quality is acceptable.

If individual gears are decided upon, results will be better, as they can be treated independently in every process. However, they cannot be of the highest quality if they are finished with a cutter; we must use gears in which the teeth are ground as the last operation.

What, then, is the best method of producing these gears cheaply? We must begin with the design of the transmission itself; a badly designed gear may be impossible to produce cheaply, and a badly mounted gear may not run satisfactorily, no matter how accurately it is finished. The design of the details must allow cheap production, and the assembly must meet the conditions necessary to good running and reliability, so far as we know them.

The essential details of the modern transmission are (*a*) gears, (*b*) shafts, (*c*) bearings, and (*d*) casing.

Tooth Loads Are Not Established

There are very few reliable data as to tooth dimensions for high-duty gears. Minimum sizes of the teeth of case-hardened gears cannot be given until considerable research work has been done. Running-tests on hundreds of thousands of gears over a period of many years demonstrate that gears with accurately finished teeth, mounted in rigid alignment, will run silently at practically all speeds if not overloaded. Bench tests and chassis tests do not give the same results when gears are mounted and run under the same loads.

Gears with teeth accurately ground will carry more load than cut gears of the same dimensions; but the most accurately finished gears will be noisy if overloaded or if they do not run in good alignment, and they will wear quickly and become gradually more and more noisy.

Gears of the highest accuracy will be quiet in some chassis and noisy in a chassis of different design, but results do not seem to be much different with unit or independent mounting of the transmission.

Gears of the same degree of accuracy will run quietly in some transmission cases and be noisy in others of exactly the same design, and pairs of gears with inaccurate teeth may run quietly.

Transmission gears with hardened and ground teeth, running at about 2000 ft. per min., may have a maximum pressure of about 1200 lb. per in. of tooth face, with temporary overloads.

Full-depth teeth are more easy to finish accurately and have better running-qualities than stub teeth. The most satisfactory all-round results are attained with a 20-deg. pressure-angle, and the full, accurate and complete involute is the most satisfactory form of tooth.

Lightest Designs Cannot Be Best

It is difficult to make gears of good tooth proportions if light weight is accepted as the guiding principle of transmission design. Small numbers of teeth in the constant-mesh, first-speed and reverse pinions are common, and they do not allow good tooth contact. Center distance between the mainshaft and the countershaft must be enough to permit at least 18 teeth in the smallest pinion. More desirable figures are 20 teeth for small cars and not less than 24 for the larger cars. With these minimum numbers of teeth, undercutting need not occur, special designs of tooth with long arcs of contact will be possible, all pinions can be made separate from shafts so that they can be cheaply machined and heat-treated, shafts can be made of generous size, and accurate mounting will not be difficult.

Forms of gear blanks should be simple to permit low cost with high quality, and this combination is most easily attained when cluster gears and gears solid with shafts are avoided.

There is no difficulty in keeping the variety of gear sizes small. Good ratios are easily found in a four-speed transmission with only nine gears, having only four different numbers of teeth. Except for very special cases there is no excuse for a transmission with ten gears, each with a different number of teeth. It is much easier to produce four different gears than ten different gears, and troubles in tooth finishing are easier to find with the smaller variety of teeth.

The rounding of teeth of clashing gears is nearly always badly done. They should be rounded in such a way that there is no possible chance for the working surfaces of the teeth themselves to be upset in gear changing. With long-addendum teeth, care should be taken that no contact takes place at the tips of the teeth when clashing.

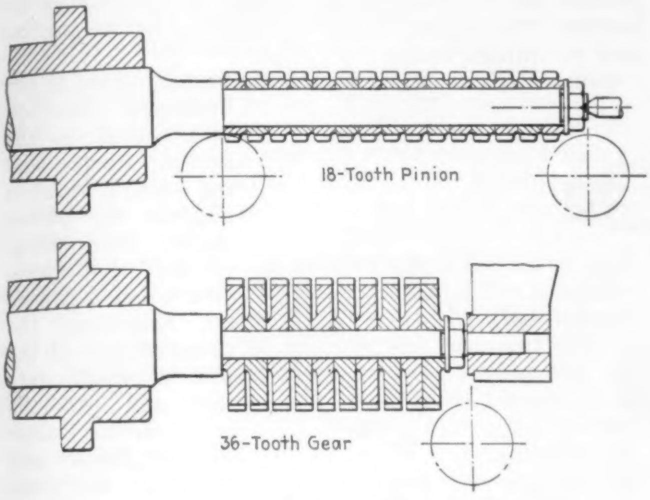


FIG. 2—HOLDING GEARS FOR ROUGH-CUTTING

The Upper View Shows 15 of the First-Speed Pinions Mounted on One Mandrel for Hobbing. The Lower View Shows 10 Third-Speed Gears Ganged for the Same Purpose

TRANSMISSION-SHAFT REQUIREMENTS

Good-running gears are an impossibility unless shafts are strong enough to keep teeth accurately in contact when under load. Long flimsy shafts must be avoided. Shafts must not bend or be forced out of line by compression of oil-films in bearings. Bending can be overcome by making the shafts large enough in diameter. Proper disposal of bearings is necessary to keep shafts in line.

For general engineering, the splined shaft is usually avoided as too costly except where absolute security is essential. It has many virtues as used in the modern transmission, and methods of making have brought it within reach for the cheapest car. It can be produced as an interchangeable part within fine limits of error.

The best form of splined shaft for both fixed and sliding gears is one on which the gears are fitted at the bottom of the splines. This surface can be finished with practically as great accuracy as a completely cylindrical surface, and the holes in the gears can be ground with no more difficulty than if they were completely cylindrical.

Shafts can be finished in the grinding machine, allowing very fine clearances for the gears with no hand fitting whatever. Gears can be made to slide freely with not more than 0.0005-in. clearance between the hole and the shaft, and small clearance is of considerable assistance in maintaining gear-tooth alignment, although its value is not always fully appreciated by either designers or producers. Fixed gears can be made with virtually the same clearances as sliding gears, and broaches can be the same for gears on both the main shaft and the countershaft.

Taken all around, the six-splined shaft meets the requirements of cheap assembly, close fits, easy working, good alignment, maximum strength, interchangeability, low cost and complete security. Lubrication is easily maintained, and very little backlash between keys and slots in gears need be specified.

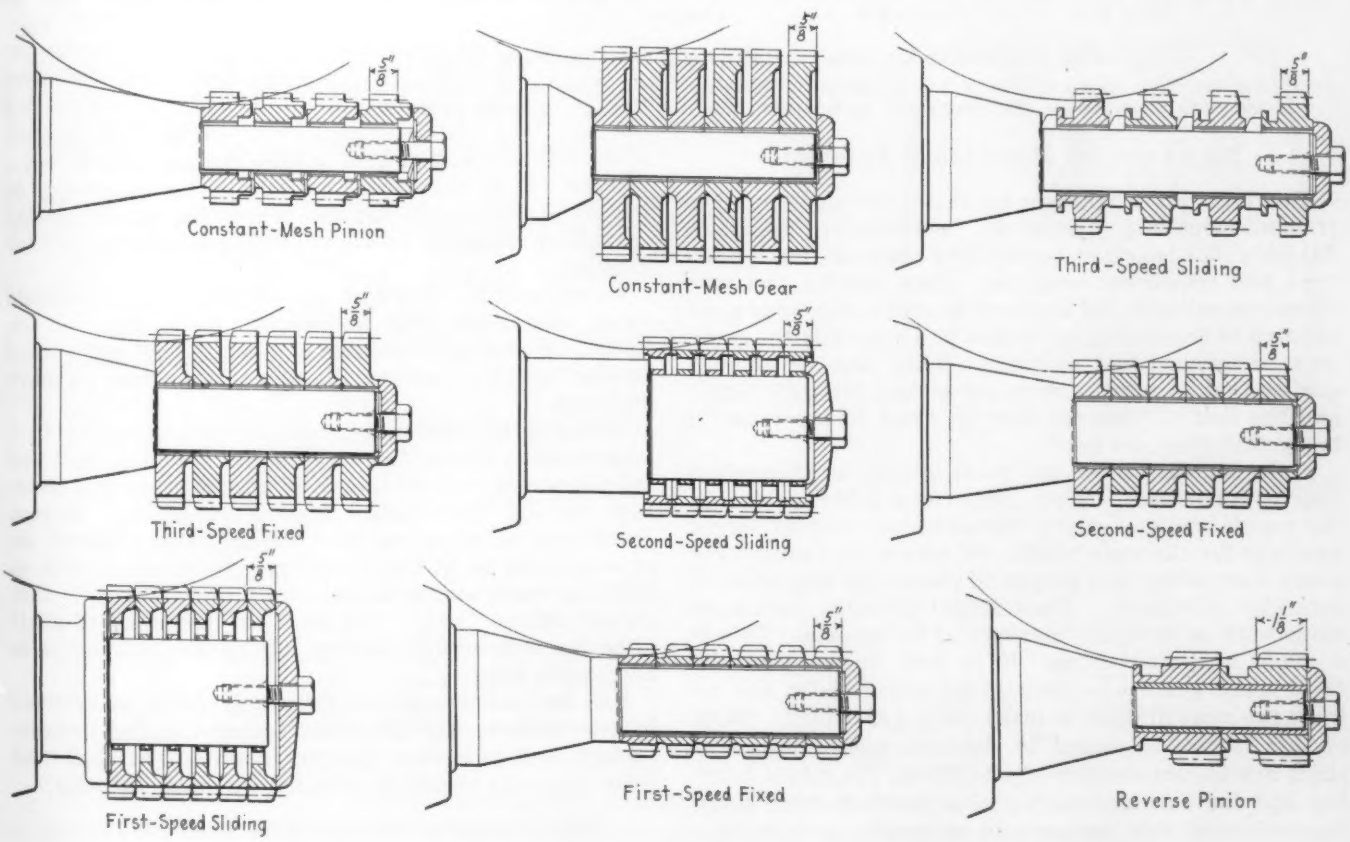


FIG. 3—GEARS MOUNTED IN GANGS FOR FINISH-GRINDING WITH FORMED WHEELS

A Group of Each of the Gears in the Transmission of Fig. 1 Is Shown Mounted on a Stub Mandrel as Proposed for the Final Operation of Grinding the Tooth Contours

It is not necessary to harden splined transmission shafts as, in a properly proportioned unit, they can easily be made large enough to provide generous sliding surfaces that will not wear.

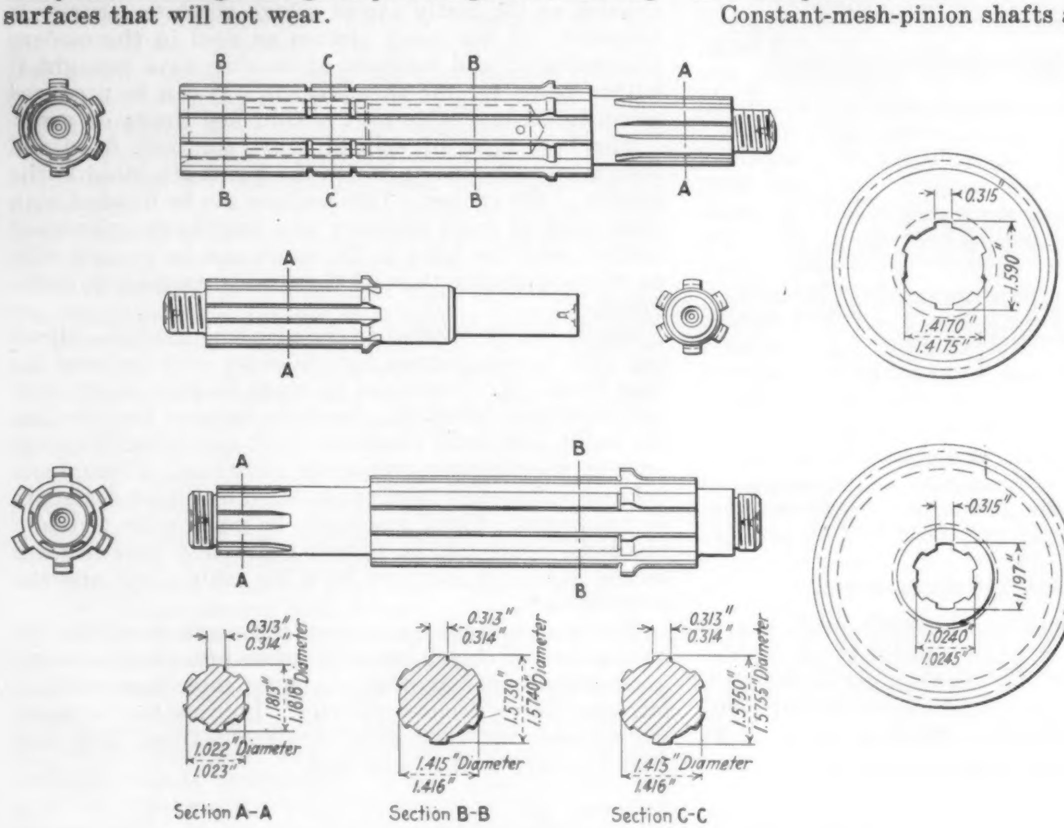


FIG. 4—DETAILS OF SHAFTS FOR SMALL TRANSMISSION

Shafts for the Unit Shown in Fig. 1 Are Designed To Require Broached Holes of Only Two Sizes in the Gears. The Shoulders on the Shafts Are Interrupted To Allow Through Grinding of the Splines

SELECTION AND MOUNTING OF BEARINGS

Bearings of six different types are commonly used in transmissions: Ball-bearings, solid-roller bearings, flexible-roller bearings, taper-roller bearings, plain bearings, and end-thrust bearings. They may be, and very often are, selected and disposed in such a way that quiet running is impossible, no matter how carefully the gears may be finished and mounted. They may be of such quality that they make more noise than the gear teeth; and the best of bearings may be fitted in the cases so badly that they are noisy.

Plain bearings have one great virtue; in themselves they are noiseless. They give remarkable service in the countershaft of many transmissions and as spigot bearings for the main shaft. Of course they must have ample dimensions and proper oil clearances and must be carefully lubricated. Plain spigot-bearings should be made with as little oil clearance as is feasible. This is a much neglected detail. It is well known that the third-speed gears of a four-speed transmission are always the most difficult to make quiet under load. Much of this trouble is caused by displacement of the main shaft due to compression of oil-films in the spigot bearing and the constant-mesh-pinion bearings. In many transmissions this amounts to as much as 0.003 in., which is enough to convert quiet third-speed gears into howlers. This defect is aggravated when the main shaft is spigoted into an overhung constant-mesh pinion. The greater the overhang is, the greater is the possible deflection. The spigot should be seated as far as possible into the pinion shaft.

Constant-mesh-pinion shafts are best mounted in two bearings, one on either side of the pinion itself, and far enough apart to support the pinion rigidly. Undoubtedly, defective operation is often caused by spigoting the forward end of the pinion shaft into the end of the crankshaft. Unless the crankshaft and the gear shaft are exactly in line, misalignment of the gear shaft will certainly result, with consequent gear noise. Although the crankshaft and the gear may be carefully aligned when new, they are easily thrown out of true by unequal wear in their bearings. The end of the crankshaft nearly always whips because of deflection under varying stresses in its cycle of operations and cannot make true concentric revolutions. It is suggested that the best construction is to extend the crankshaft and mount the clutch on this extension, coupling to the transmission with a flexible member.

Countershaft bearings of whatever type should have capacities well above the loads imposed on them. If two ball-bearings are used, only one should be the locating bearing, the other being free to move endwise.

There is no need for a special thrust-bearing in a transmission except for very special service. Ball and roller-bearing makers advise not more than two bearings for any one shaft. This is reasonable, because clearances in good bearings rarely exceed 0.0003 in. It is not easy to fit three bearings on one shaft with so little oil space and with uniform oil clearances so that oil will run perfectly. The slightest distortion of shaft or casing will destroy bearing lubrication, causing noise and undue wear.

Ball and roller-bearings are rarely fitted as directed by the makers, the imperfect fitting causing unsatisfactory and irregular running results. All ball and roller-bearings should be selected for quiet running.

TRANSMISSION-CASE ACOUSTICS REQUIRE STUDY

It would be difficult to find any piece of mechanism that has given better service in respect to reliability than the ordinary transmission. It has stood by the

automobile engineer since cars were first made, and it is still without a rival. If it could be made noiseless it probably would remain supreme for a long time. Efforts to make this unit quiet have been thwarted, principally, by inaccurate gears. This obstacle now is removed and quiet gears of uniform quality can be guaranteed, each pair tested for silent running, with no rejects or scrap. Entirely satisfactory bearings also are available, and there is no excuse for the design of flimsy shafts.

Developments that will secure refined operation may be confined principally to the casing and the arrangement of bearings. The problem is not easily solved, neither is it hopeless, but it never will be solved so long as the motor-car engineer makes light weight the beginning and the end of all in his work on transmission design. Sufficient metal to secure rigidity for correct tooth-contact can be accepted as an indispensable requirement. Undoubtedly the greatest difficulty will be encountered when troubles are other than mechanical inaccuracy and the study of gearbox acoustics begins. Resonance in transmission cases has not been made the subject of special research. Objectionable noises seem both to be created in the case and to be echoed in it from other mechanisms.

Experiments are needed on the shapes and sizes of cases, on the method of mounting in the chassis, and on fore-and-aft connections. These experiments must be made with actual road-tests, using the most accurate gears and bearings. One trouble that is not often recognized, but which seems to be present to a greater or less extent in all transmissions, is noise from oil-churning. In some units, in which this has been so bad that it was attributed to poor gears, it has been remedied by inserting baffle-plates.

It can be accepted that the transmission problems of the future are principally those of the case. If this detail can be mastered, the conventional transmission in its simple form will serve the motor-car engineer for a long time, and be silent, cheap and reliable. Complicated and expensive forms of gearing will not be necessary.

Free-Wheel Mechanism Deserves Study

A recent development, if successfully applied, may give prolonged life to the ordinary transmission. It is known as a free-wheel mechanism and it has an attraction for the driver as well as for the maker of cars. Very likely the device is worth considerable attention from the car engineer who is considering transmission improvement. If perfected, it will not only remove the bugbear of gear changing but it also should prolong the life of the unit and increase the efficiency of the car.

It cannot be said that we have sufficient knowledge or data to enable us at once to design and produce the ideal transmission. We do know enough, however, to make a unit in which the worst features of many others can be avoided and in which the best features of gear-tooth development can be utilized. Most motor-car makers know that calamitous results may follow the initial production of a radically new design. It is almost impossible to foresee what will happen to any mechanism in public use. Stiff tests, no matter how long a period they may cover, often are misleading. The capacity of the public for revealing weaknesses and defects is unlimited; and the public is the only final judge.

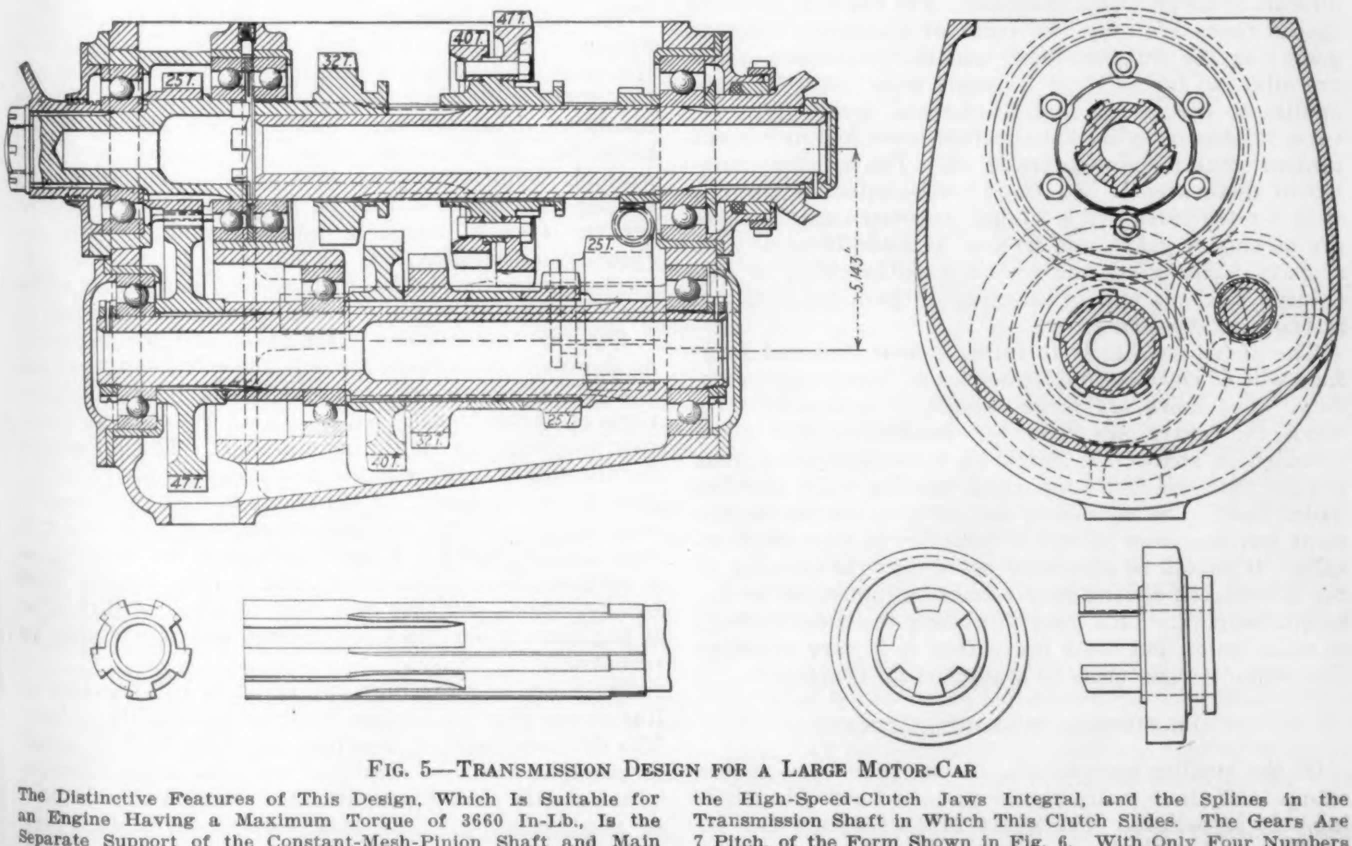


Fig. 5—Transmission Design for a Large Motor-Car

The Distinctive Features of This Design, Which Is Suitable for an Engine Having a Maximum Torque of 3660 In-Lb., Is the Separate Support of the Constant-Mesh-Pinion Shaft and Main Transmission-Shaft without a Spigot Bearing. At the Bottom of the Figure Are Shown the Third-Speed Sliding-Pinion, with the High-Speed-Clutch Jaws Integral, and the Splines in the Transmission Shaft in Which This Clutch Slides. The Gears Are 7 Pitch, of the Form Shown in Fig. 6. With Only Four Numbers of Teeth, the Ratios Are 1.00 to 1, 1.50 to 1, 2.35 to 1, 3.54 to 1. and 3.54 to 1

Further, there is often much difference between the experimentally made and the factory-made article.

To follow the moderate course of progress, a design of transmission is submitted herewith that is believed to be neither a freak nor an experiment. It meets most of the conditions that we know are required for both good running and cheap production, making use of ground gears which, as gears, can be guaranteed to be silent when running. No departure is made from conventional methods of gearshifting or chassis mounting or of standards in detail.

Production of gears of the highest quality has been kept in mind in the design of the gears. The use of formed-wheel grinding for tooth finishing is adopted as a method which gives extreme accuracy and fast grinding, allows for the cheapest tooth-roughing, and covers the widest range in pitches and face widths and hardening distortions. Gears made from case-hardening nickel-steel are adopted as giving the best satisfaction.

A Small Four-Speed Transmission

The design of transmission shown in Fig. 1 is suitable for a so-called 15-hp. (Royal Automobile Club rating) car with an engine displacement of 2350 cc. (143.4 cu. in.). It can be mounted either independently or as a unit with the crankcase. There would be little danger in putting this transmission into production with very slight delay. Details will be discussed following the principles which have already been outlined respecting (*a*) design and (*b*) production methods.

The gears, so far as numbers of teeth are concerned, are only four. This is important, as it gives the smallest possible variety of tooth problems, which are the most difficult of all problems to master. For the four forward speeds there are only two pairs of distinctly different gears; as the constant-mesh and the first-speed gears are alike, so far as tooth finishing goes; and the same applies to the second and third-speed gears. The reverse idler-gear is like the constant-mesh and first-speed pinions, making nine gears in all. The smallest number of teeth used is 18. Good tooth-contact is possible with 8-pitch teeth and a 20-deg. pressure-angle. There are no cluster gears, and no gear is made integral with a shaft. This gives the widest possible choice of machining methods and in selection of gear material and methods of heat-treating.

The gears are simple in form, so that dies and forgings will be cheap. Only two sizes of broach are necessary. The holes are large enough to assure security when the gears are held for machining and when mounted on shafts. It should be noted that every gear is mounted close to a supporting bearing when running under load. The method of spigoting is not an experiment but has been proved in practice to give good results. It should be especially noted that the running of the third-speed sliding-gear cannot be influenced by the spigot bearing. This gear is always the most difficult to make quiet, but tests prove that it is very satisfactory when it runs close to a supporting bearing.

Production of Ground Gears

Of the smaller gear shown, 15 can be hobbed at one set-up. All these gears can be ganged for tooth grinding. It is believed that gears of this design can be tooth-ground to the highest degree of accuracy at a cost that will compete with any other method of tooth finishing. Figs. 2 and 3 show how the gears can be ganged for rough-cutting and finish-grinding.

To allow for tooth distortion in heat-treatment, 0.004 to 0.005 in. of stock should be allowed at the sides of the tooth for grinding, by using a thin cutter. The outside diameter of the blank is turned to finished size, and from zero to 0.010 in. of stock should be left at the root of the tooth for grinding.

Face grinding must be carefully done to get satisfactory results. It is evident that tooth grinding in the way suggested will not be uniform unless the face grinding is very accurate in relation to the surfaces of the gears. The hole and spline dimensions shown in Fig. 4 are easily worked to.

The Center Distance Must Be Ample

It is a common mistake for designers to select a center distance too small for good gears. The center distance between the shafts, the gear center-distance, is the smallest that can be advised for this transmission. Probably the unit would be more satisfactory if the center distance were greater. Certainly the gears should give a better performance if they were made larger in diameter, but they do not need wider faces. The best tooth-contacts are not possible in a pinion with a low number of teeth, and a small-diameter pinion cannot be made separate from its shaft without making the shaft itself too small properly to support the gears. Holes in small pinions cannot be large enough for good mounting nor to support accurate and cheap machining. The governing dimension of the transmission is the center distance between the shafts. Nothing is gained by making it small, and much is gained by making it great.

The splined shafts are shown in detail in Fig. 4. They are made with splines of only two sizes. The splines on the constant-mesh-pinion shaft for both the pinion and the clutch spider are the same and are finished in one operation. The working limits shown are easily adhered to. It is recommended that splines be finish-ground, facilitating close and at the same time easy sliding fits. There should be no hand-fitting whatever, for the sake of complete interchangeability and the cheapest assembling. It should not be necessary to harden either the shafts or the sliding member on which the first and second-speed sliding-gears are mounted.

For the transmission main-shaft and the constant-mesh-pinion shaft there are only three ball-bearings and one spigot bearing, the same as in nearly all transmissions of conventional design. There are also, as usual, only two bearings for the countershaft. The suggestion for the spigot bearing is not new although the construction is not common. As shown, it is well supported at some distance from the constant-mesh pinion, and it is very lightly loaded. A loose bushing is not advised, as it adds another oil clearance and it may become fixed by the chance entrance of a chip or piece of dirt after it has been in service a short time, and it will then be eccentric.

There are no more than two roller or ball-bearings in line on one shaft, a feature endorsed by bearing makers. The distance between bearings has been kept as small as possible, and this, combined with the large diameter of the shafts, should prevent the deflection that is fatal to good running. The long roller-bearing has been chosen to support the layshaft as close as possible to both the constant-mesh gear and the third-speed coun-

tershaft-gear. The lubrication should be satisfactory in a gearbox of the design shown.

Resonance Avoided in the Case

The design of the case shown is not offered as ideal, nor as one in which gears will be guaranteed noiseless running. As before stated, we have very little to guide us definitely in fashioning this detail. It is possible that gears running in this case will be quiet in one chassis and not in another of even the same design.

Use is made of the principles of design known to give the best results. The case is as small as is practicable, leaving as small sounding-board areas as possible. It has been observed that transmission cases with large open spaces are more resonant than others. Noises either transmitted or created by flat surfaces have also been noted. Curved surfaces should not vibrate and are stiffer for the same weight than flat walls. In the pattern of casing suggested are shown internal ribs connecting the outer walls with the metal in which the bearings are housed. As there are two of these central bearing-supports, one for each shaft, the case should have considerably more rigidity than the usual pattern. It is suggested that an experimental case could be made by arranging diagonal ribs on the sides and bottom of the case without altering any internal details. They would certainly stiffen the case and might assist in absorbing vibrations.

The method of mounting the case in the chassis is important. It should be mounted in as complete isolation as possible in respect to connections with the engine shaft and the propeller-shaft, as well as the fixed surfaces by which it is secured to the frame.

What are called period noises are most difficult to deal with. The main difficulty is to locate the *source* of the trouble. It is not always certain whether it is in the transmission or comes from some other unit. Improvements in the design of transmission cases may assist materially in curing this trouble, which sometimes disappears with a change in speed.

Oil splash, if objectionable, can be dealt with only by observing the running conditions and applying experimental remedies until a cure is found.

Design for a High-Quality Car

Another design of transmission is submitted in Fig. 5 as being suitable for large cars in which refined running is especially desirable and costs are not so important as for smaller cars made in large quantities. The gears themselves can be produced cheaply, for the same production routine can be followed as for gears in the smaller transmissions, with the exception of the third-speed sliding-gear. The clutch teeth on this gear must be ground on the sides so that they will have all possible bearing on the sides of the deep splines of the main shaft. Novel features are that the main shaft is without a spigot and engagement for direct drive is made when the clutch teeth on the third-speed sliding-gear are pushed through the ball-bearing and lock with teeth on the constant-mesh-pinion shaft.

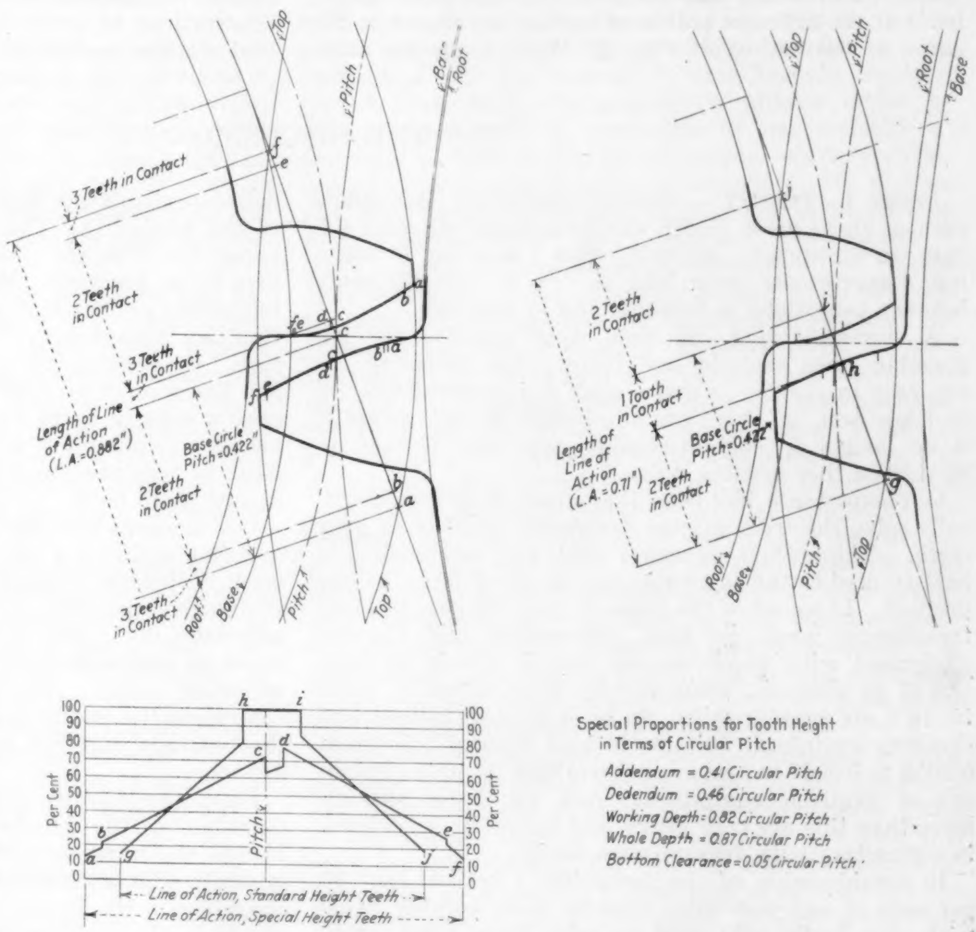


Fig. 6—Tooth Forms for Large Transmission

At the Left Are Shown the Special Forms of High Teeth for the 25 and 47-Tooth Gears Used for the Transmission Shown in Fig. 4. Corresponding Teeth of Standard Proportion Are Shown on the Right for Comparison. At the Bottom of the Figure Is a Diagram Showing, for Each Form, the Percentage of the Total Load Borne by Each Tooth as It Passes Through the Line of Action

No radial displacement can occur, such as is always possible with the ordinary spigot-bearing design when the oil-film is compressed by tooth pressure of the gears.

All the sliding gears are supported on a large shaft mounted between two ball-bearings. The constant-mesh pinion also is mounted independently between two bearings. All the countershaft gears are supported between bearings. There are no overhung gears in the transmission.

On the countershaft there are three bearings in line. These should be selected with a minimum clearance be-

tween the balls and races of 0.0005 in. Loading pressures of indirect gears should not affect the running of the constant-mesh pair.

The gears in the large transmission have been designed with special forms of teeth having a long arc of contact. The tooth designs are shown at the left in Fig. 6, and at the right are shown the standard tooth-forms that usually are adopted. Comparative tooth-loads at the different points of contact are shown in the curve at the bottom of Fig. 6. When teeth are accurately finished the special long-addendum forms are of practical value, although they are not of much value in an ordinary cut gear.

The two transmissions shown are not suggested as the last word in transmission design. They are given as examples of construction that may be helpful to those who wish to make the most economical use of gears with ground teeth. They are intended also as illustrations of principles to be followed to secure the best running-results from accurate gears.

THE DISCUSSION

PERRY L. TENNEY[2]:—Before considering statements such as those made in Mr. Orcutt's paper, we must adjust our viewpoint. Anything that I may say in seeming disagreement with him is due to the difference between conditions in England and in America.

A statement that has been most effective for impressing upon men in our factory the necessity for accuracy in gearing is that a gear is a constant-velocity multiple cam. If there are any humps in such a cam it it no longer a constant-velocity cam, and it sets up vibrations that produce noise.

Our experience has been that good cut-gears practically solve the transmission designer's problem of gear teeth. This refers to gears that are machined and heat-treated to the same standard as other items of our product. If we allow the heats to vary 50 deg. in heat-treatments, when we have pyrometers and furnace equipment with which we can hold it within 25 deg., and if we allow the gears to vary from 0.0005 to 0.005 in. in their contour when we have hobs, machines and checking equipment suitable to hold them within from 0.0002 to 0.0005 in., we are not working up to the standard of available equipment. Any cut gears varying more than this are poor gears, and cannot be considered in connection with transmission design.

In consideration of the foregoing, I believe that 95 per cent of our gear-noise troubles have nothing to do with gear teeth and, until we solve these other problems, gear grinding will not help. I have seen very few transmissions made well enough to justify grinding the gears. It is only after the other problems are properly solved that gear grinding will show its real value. It will better a good transmission, but it will not help a poor transmission. What seem to be an exception is the transmission of a large truck in which, owing to an engine change, it was necessary to hold the backlash between limits of 0.003 and 0.005 in. on a five-pitch 50-tooth gear meshing with a 17-tooth pinion. It was found impossible to hold the gears within these limits when cut and heat-treated in the ordinary way, so we ground them. This prevented gear clatter, but it did not reduce the noise otherwise; the gears were no better than the experimental cut-gears when matched within the specified limits of backlash.

Mr. Orcutt states that designers are largely responsible for the slow progress in transmission design. It is the commercial situation which demands conservatism, and it controls the designers as well as all the rest of us. This is in line with Mr. Orcutt's statement that light weight is a false aim. The ratio of foot-pound-hours to dollars controls the design of transmissions, as well as of the whole car. This condition is referred to in the paper, but it is not given the importance that we must give it in America. Mr. Orcutt's recommended starting-points or bases of design are far lower than those that are accepted in American intermediate-gear design. He recommends a maximum pressure of 1200 lb. per linear inch on gear teeth, while most of our successful designs carry from 2400 to 2900 lb. He recommends a minimum of 20 or 24 teeth for a pinion, while most of our commercial designs include pinions with as few as 16 teeth.

Our transmission design is based on the foot-pound-to-dollar ratio; not on a minimum number of pinion teeth. Modern materials permit transmission operation with a pressure of 2900 lb. per in. in second gear and 5400 lb. in low gear or reverse. Tooth stresses based on cantilever calculations determine the pitch and minimum width; reasonably well-known wear-factors determine the additional width needed, and the size of the bearings required determines the minimum center-distance.

From the foregoing factors and the gear-ratio requirements, the numbers of teeth are determined. Should the number in the pinion be less than is permissible with a standard tooth-form without undercut, according to the Brown & Sharpe formula, as occasionally it is, the problem is solved with a modified addendum based on the geometry of involute gearing, not on hand-book formulas. In this way is obtained the smallest and lowest-cost transmision that will meet the requirements.

The same basis of design for engines, axles, springs, and even for bodies, makes possible the modern motor-car at a price within the reach of the multitude. Foot-pound-hours per dollar serves also as the basis of our highest-priced cars, and this relationship typifies American motor-car design, in contrast with the highly refined individualistic cars at prices beyond the reach of the multitude which typify British design.

Confirmation of our attitude is found in one of the greatest uses we make of ground gears. Whenever we place a transmission in a new car and encounter criticism because of gear noise, our first answer is to furnish a set of ground gears in which the customer cannot find a defect. If these gears do not cure the trouble, the problem is in the application of the gears and not in the gears themselves; and we must work on kinetic values, vibration, resonance and such problems. During the four years in which we have used this method, ground gears have never cured the trouble.

I believe that Mr. Orcutt's condemnation of the in-

[2] M.S.A.E.—Chief engineer, Muncie Products Division, General Motors Corp., Muncie, Ind.

tegrally forged cluster-gear is a little too severe. Some of his statements are true and others were true for such forged clusters as were available 10 or 15 years ago; however, modern upset-forging methods, controlling the grain-flow and structure, together with modern heat-treatment and modern gear-cutting, enable us to produce a cluster gear that is more accurate than a built-up cluster, because of the accumulation of errors in the latter.

We have found grinding to be valuable on our forged cluster-gears, especially for salvaging the small percentage of gears that develop some irregularities. Also, we have found the two-piece cluster-gear to be a ready solution when a full-ground set is required. Making two gears integral with the shaft and two on a sleeve allows all of the gears to be form-ground, with far better control of eccentricity and key fits than is possible with a fully built-up design.

I am much surprised that Mr. Orcutt apparently approves the semi-hard splined shaft, when his recommended grinding-practice lends itself to the highest development of a hardened splined-shaft. Under the pressures that we have found practicable for gears, with the permissible deflection of splined shafts and the other factors that determine the size of a splined shaft, it is necessary to use a hardened shaft to secure permanence of fit when splines and gears are stressed as they are in commercial usage.

The fundamentals stated by Mr. Orcutt, applied with the foregoing principles, produce transmissions that are satisfactorily quiet and of much higher capacity at a given cost than those submitted by Mr. Orcutt. The application of these ideas exemplifies the difference between the British and the American viewpoints. I heartily recommend our consideration and acceptance of the greater portion of the fundamentals of Mr. Orcutt's paper, and present these differences, not as opposite views, but as modifications and applications of the same views.

Form-Grinding Process Preferred

Mr. Orcutt infers that gear-grinding for a transmission can be done at about the same cost as gear-cutting. We have tried, but so far have failed miserably, to substantiate this. We find that the total cost of gear-cutting in a motor-car transmission, including all equipment and perishable tools, is a relatively small portion of transmission cost, and that entirely eliminating this cutting would not eliminate 5 per cent of our so-called gear problems, because most of them really are due to mounting, deflection, torsional vibration, resonance, and other items not directly connected with gear teeth. When gear-grinding can be done at the cost of finish-cutting, and when transmissions can be refined to such an extent that gear-grinding is justified, better transmissions will be made.

The job immediately ahead of the designer is to work out his other problems, such as those that arise from an adaptation of a transmission—perfectly good on one model—to a new engine, a new car, a new clutch, a new propeller-shaft, or a new mounting of the same engine; and to all the problems, in resonance, in torsional vibration, in deflections, that this change brings about. We are kept busy in following up these items, without necessarily changing the gearset itself.

Mr. Orcutt makes but one slight reference to the type of grinding considered in his paper, form-grinding, and he makes no comparison between that and the generating type of grinding, which is much in evidence.

Having followed the gear-making industry from the old days of formed cutters to those of shapers and hobs that work on the generating principle, we at first decisively discarded the idea of form-grinding in favor of generating machines. However, after some years of work along this line, we found that we could get better consistent results from the form type of grinder. Investigation into the reasons for this brought the conclusion that, while the generating process might be ideal, it apparently is impossible or impracticable at this time to build a generating grinder without violating all principles of grinder construction. We did not like the forming-cam and pantagraph principle for formed wheels, but by this principle it was possible to build a genuine grinder, and a comparison of results from machines of the two types caused us to abandon the generating machines for production and use the formed-wheel type of grinder. In other words, we have not seen a generating gear-grinder that does not violate many of the fundamentals of a good grinding-machine, but it is possible to build a formed-wheel grinding-machine that is a good grinder, and, whether we like its fundamentals or not, it makes good ground-gears.

H. F. L. Orcutt:—Deciding between improving the transmission case or the gears seems to be as hard as deciding which was made first, the egg or the chicken. Noise is always the great question; it has been practically eliminated in every other unit of the car, and I feel that the public will demand greater refinement in this respect. Mr. Tenney states that ground gears will not help a poor transmission, and I say that poor gears will spoil an otherwise good transmission.

I believe that progress in transmission cases will not go very rapidly unless the motor-car maker begins to use, experimentally at least, transmissions with gears of the utmost accuracy. If such gears are used and other troubles develop, the troubles must be eliminated as rapidly as possible. Commercial conditions are the same on both sides of the water, in that we all are obliged to produce and sell at a price that the public will pay; but they are different in that, in Great Britain and on the Continent, cars are not produced in very large quantities, and I believe that the demand for refinement is a little ahead of that in America. At the same time, most of the American cars in which I have ridden have wonderful qualities, especially when their prices are taken into consideration.

Light Loads Make Quiet Running

In regard to pressure on gear teeth, we have found the best results, in about 50 or 60 different designs, to be obtained when the load does not exceed 1200 lb. per in. of face. In one English car, which is smaller than any made in America, I can account for the quiet running of its gears in no other way than because the tooth loads are even lower than that figure.

Broadly speaking, low loads on teeth of high quality are a help in the production of silent transmissions. Even in cars in which I know the gears to be ground as accurately as they can be, the results are always bad with pressures of 6000 lb. per in.

We have found that eccentricity does not very much affect the running of a gear if the teeth and the spacing

are correct. The involute tooth adapts itself to eccentricity and a considerable variation in center distance without the slightest effect on noise.

Experience on many transmissions shows that there is no necessity for hardening the shafts if they are large enough, are made from good material, and are ground accurately with not too great a clearance between the sliding gear and its shaft. I have found that clearances in the best-running gears do not exceed 0.0005. That clearance is easy to maintain and is more satisfactory than the same clearance in a cylindrical shaft, because the oil space in broken up by the splines and there is only a slight amount of sliding action. In the transmission of one of the best-known cars in England, the shafts are milled, and it is one of the best-running transmissions of which I know.

The cost of tooth grinding is vital. Without low cost, the general adoption of the process will not be possible. My remarks on cost are based on actual experience in the cost of furnishing accurate gears; not ordinary cut-gears. Grinding is the cheapest way of producing such gears, and I think that the time is not far off when we can produce ground gears very economically.

I endorse Mr. Tenney's approval of form-grinding. Good work is done by generating machines, but I do not think it is possible to obtain both low cost and uniformity of quality by the generating method so well as by the formed-wheel method.

A Field for Investigation

A. B. Cox[3]:—Mr. Orcutt's statement that there are few reliable data as to tooth dimensions for high-duty gears suggests that it is strange that manufacturers have paid more attention to almost every other feature in the design of gearing than to tooth contact. A thorough investigation of this rather neglected field of research should pay large dividends in cheaper, quieter, stronger and longer-lived gears.

In Fig. 6, has Mr. Orcutt considered the shafts and gear teeth as being formed of perfectly rigid, nonelastic materials with no lubricating films between teeth; or has he taken into account the oil-film compression and the deflection of the teeth—which is about 0.001 in. on full-load torque—both of which tend to equalize the tooth pressure but not the tooth-breaking stress, when two pairs of teeth are sharing a load? Has he made his deduction for gears that are new or for gears that have run long enough to self-correct the tooth form in the manner described for Krupp Nitor-steel gears, by H. Hofer[4]? Shaft deflection tends to decrease the average number of pairs of teeth in contact; first, by decreasing the effective working-depth of a tooth and, second, by increasing the effective pressure-angle. Taking into account this factor and that of manufacturing tolerance, it is likely that Mr. Orcutt has integral contact between the gears, in which case he will have the operating conditions that both Mr. Hofer and I[5] independently have found to be so highly desirable in gearing. A report of the benefit of integral contact between high-speed gears has been given recently by I. Short[6].

MR. ORCUTT:—In Fig. 6 only pure tooth-loads are considered, as illustrated by the small diagram in the lower left-hand corner, and only new and accurately ground gears.

RALPH BAGGALEY, JR.[7]:—What is to prevent using a finer pitch to get the required number of teeth in the pinion without increasing the center distance or the size of the gears? What is the smallest clearance that can be used in a bronze spigot-bearing without danger of seizure?

MR. ORCUTT:—The main fact in deciding on the pitch is the strength of the teeth. Good contact can be obtained in small pitches, but there is danger that the tooth load will be too high. Clearance in the spigot bearing depends on the diameter; about 0.0015 in. would be right for a medium-size spigot-bearing, but the clearance should be more for a large bearing and might be less for a small one.

The Effect of Baffles

M. C. HORINE[8]:—Has Mr. Orcutt had any experience with beveling instead of rounding the teeth on the engaging end?

Do not baffles for reducing the noise of oil-churning involve additional power loss, and is there not a possibility of reducing the noise by designing the interior surface of the case for a smoother flow of oil? Easily flowing oil will not produce a noise.

What is Mr. Orcutt's opinion as to the relative merit of shafts placed side by side or one over the other in relation to the oil-churning noise, and also as to the design in general? Is not the frame of the car, particularly in the case of a transmission mounted directly on the frame, one of the greatest sounding-boards?

What objections has Mr. Tenney to generator gear-grinding, other than cost?

MR. ORCUTT:—I think there is no choice between beveling and rounding the ends of the teeth, but it is important to make them so that the tooth surfaces will not be upset. It is also important, on fine-pitch gears or long-addendum gears, to prevent clashing on the points of the teeth. I do not know that we have tested the efficiency in connection with oil baffles. The tendency is to use a thinner oil with good ground gears than we used when we thought something like molasses or sawdust was needed to deaden the sound. With such an oil, in not too great a quantity, I believe that baffling may increase the efficiency.

I believe that a transmission with one shaft above the other is likely to be more quiet, but the side-by-side design is better for assembly, especially in large units.

Mr. Tenney's remark, that there is much about which we do not know, applies to Mr. Horine's question about the relation of the frame to noise. I can see how the frame might transmit noises but not how it could produce any noise.

MR. TENNEY:—My objections to the modern generating grinding-method are that the mechanism seems to be too delicate to control the weights and the forces within the degree of accuracy required, and that every generating-machine I have seen involves grinding along a long line on the side of the wheel, which seems to violate all the principles of good grinding.

[3] M. S. A. E.—Consulting engineer, New York City.

[4] See *Zeitschrift des Verein Deutscher Ingenieure*, Oct. 30, 1926, p. 1460.

[5] See *The American Machinist*, May 24, 1928, p. 848.

[6] See *Power*, May 1, 1928, p. 761.

[7] Jun. S. A. E.—Assistant equipment engineer, Department of Highways, State of Pennsylvania, Harrisburg.

[8] M. S. A. E.—Manager, sales promotion department, International Motor Co., New York City.

At our first trial of it, the form grinding-machine showed itself to be a good grinder and to make good gears, because of the size, position, and bearing support of the wheel, and it has not failed since. The forming members operate the diamonds only; and the rest of the machine is simple, with brute strength rather than delicacy, something that has never been available in a grinder of the generating type.

MR. HORINE:—I assume that you have been able to obtain good results with the generating type of grinder.

MR. TENNEY:—We have ground very good gears with this machine, but we could not produce good gears continuously. We tried for two years to get production from six generating-machines. They produced many good gears, but they required continual fighting against gear-tooth problems. After everything was adjusted, some change in the tension of the tape or in a bearing at the side of the wheel would upset the adjustment.

MR. HORINE:—Our experience has been very different. We have had about four years' experience with generating-machines of various types, including some of our own design. We are securing a very high degree of accuracy, such as we were never able to get from the form grinding-machine, and I am trying to find out whether the modern form grinding-machines will give equivalent results.

MR. TENNEY:—Form grinding-machines have undergone the same improvements as cylindrical grinding during the last 10 or 12 years, while the fundamentals of generating-grinders seem not to have been changed.

EFFICIENCY TESTS OF TRANSMISSIONS

EARLE BUCKINGHAM[9]:—I recently finished some tests of the churning losses in an automobile transmission. They seem to show a practically constant torque-load with a given oil at various speeds, so that the power loss is proportional to the speed. I had expected to find the torque load to increase with the speed. Most of the loss is due to the friction of the gears in passing through the oil.

Our tests showed that the loss is less in a transmission having the countershaft underneath. We made tests with the oil at different levels, the loss increasing at a fairly uniform rate until a sudden jump came when the level was such that the gears of the main shaft touched the oil.

We tried light oils, heavy oils and no oil at all. There was much less difference in the results between light and heavy oils than I had anticipated; in fact, I believe that the loss was greater with very light than with medium oil. There was some evidence that the light oil flowed between the teeth and was thrown off; whereas the viscosity of the heavier oil, even at operating temperatures, was sufficient to prevent it from flowing in between the teeth.

JOSEPH A. ANGLADA[10]:—Of course we all desire quiet transmissions; but, since we cannot obtain them at prices we are willing to pay, why not make them so that they will emit a pleasant noise? My experience indicates that noisy gears are not necessarily less efficient than gears that are relatively silent. Has any work been done along that line?

MR. BUCKINGHAM:—Efficiency tests have shown that losses seem to be almost directly proportional to noise, and the noise to be almost directly proportional to the inaccuracies.

MR. ORCUTT:—I do not know how a music-box transmission would take.

Good ground-gears have been found, in tests by the National Physical Laboratory in London, to have an efficiency of 99.6 per cent. Poor tooth-forms may bring the efficiency down to 80 per cent or less, but good cut-gears are more highly efficient than we might expect.

MR. BUCKINGHAM:—The efficiency depends also upon the pitch. In some tests of fine-pitch gears, with speeds up to about 2000 f.p.m. and loads higher than the usual operating loads, cut gears with errors not exceeding 0.0015 in. showed an efficiency of about 99.7 per cent. With 3-pitch cut-gears, having the same degree of accuracy, the efficiency was a little less than 99 per cent. With 3-pitch ground-gears the efficiency was about 99.4 per cent. The loss with 3-pitch gears seems to be about three times that with 10-pitch gears.

MAJOR E. G. E. BEAUMONT[11]:—My remarks are from the viewpoint of a user who has had the opportunity of observing the peculiarities of many different designs. The fleet with which I have to do includes commercial vehicles of about 45 different makes and motor-cars of at least 15 different makes, with 3000 vehicles operating.

I have observed that with some chassis having all joints between the clutch and the rear axle made of metal, there has been much trouble in securing reasonably quiet running, but when one or more fabric joints have been substituted the trouble has almost entirely disappeared. Cases have come to my notice recently in which makers have tried without success to remove a difficult period from their engines, and flexible mounting of the engine by means of buffer springs of carefully calculated strength has removed the trouble. I think, therefore, that Mr. Orcutt has referred to a desirable feature in mounting transmissions with a certain amount of relief. The elimination of rigidity has much to commend it. I have found in the operation of trucks that the rate of wear and the appearance of stress in the transmission are much more marked with radius-rods and torque-arms without springs than when the Hotchkiss drive is employed.

It is possible to have too fine a fit, too great a rigidity of design. Machines that have performed considerable mileage in service settle down to the work and become quiet until they are brought into a repair shop and interfered with. As soon as new bearings are installed and accumulated looseness is removed, the noise is unbearable. The lesson seems to be that some relief from rigidity is to be encouraged.

CHAIRMAN D. D. ORMSBY[12]:—The discussion of this paper has brought out three important facts:

(1) We must make good gears, whether they are ground or not.

(2) They must be mounted properly, with adequate bearings, to assure rigidity.

(3) The car manufacturer and the user of transmission gears must cooperate with the gear producer in the design of the transmission and its installation, as the making of quiet gears is a hard problem which must have the cooperation of all concerned.

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[9] M. S. A. E.—Associate professor of engineering standards and measurement, Massachusetts Institute of Technology, Cambridge, Mass.

[10] M. S. A. E.—President, Anglada Motor Corp., New York City.

[11] Motor superintendent, Anglo American Oil Co., Ltd., London, England; president, Institution of Automobile Engineers.

[12] M. S. A. E.—Consulting and sales engineer, Brown-Lipe-Chapin Co., Syracuse, N. Y.

Special Automotive Equipment of the Army

By MAJOR LEAVEN H. CAMPBELL, JR.[1]

WASHINGTON SECTION PAPER *Illustrated with* PHOTOGRAPHS

DURING the time which has elapsed since the armistice, the leading military authorities of our Army have been giving serious study to methods and means of transportation for our armed forces. War has become so largely a matter of the use of machines, and the expenditure of ammunition by all weapons has been so greatly increased, that the rate of movement of an army is practically set by its ability to move its equipment and supplies. The horse, while a most dependable agency of transport, does not possess either the power or the rate of speed desirable in a modern army. For these and other reasons, the trend of thought is more and more toward the use of motor-propelled vehicles of all types, and the purpose of this paper is to set forth briefly the development work that has been done by the Ordnance Department since the armistice toward carrying out the duties with which it is charged in the matter of developing vehicles which are adapted primarily to operate off the roads.

> Motorization or mechanization is of greatest importance in the securing of mobility for the modern army. The paper by Major Campbell is of interest in setting forth what has been done toward that end, and his views, as expressed, may be taken as representing those of the Ordnance Department.
>
> It is a pleasure for me to take this opportunity of expressing my personal appreciation for the unfailing help in our problems which has at all times been extended by the Society and by the automotive industry.—Major Gen. C. C. Williams.[2]

In all its work the effort of the Ordnance Department is to produce what the using services want. The designs are based entirely upon the requirements of the "customer," and the words "serviceability" and "reliability" ever are uppermost in the minds of the officers in the Ordnance Department.

Unfortunately, lack of funds has resulted in little opportunity for the using services to work with modern automotive equipment. Their ideas of performance and dependability are based largely upon familiarity with the vehicles of 1917, and it is not surprising if they look askance on the idea of motorization. Their yardstick of performance of motorized equipment is the old 6-ton tank and trucks of obsolete types. Trucks and tractors that give many miles of service with but a reasonable amount of upkeep and repair now are commercially available in large quantities. The mileage life of special automotive vehicles such as the tank is being constantly increased.

All development and improvements are based largely upon the manufacture of units in quantity, with tests under every conceivable condition of operation. The commercial industry each year manufactures automotive vehicles by thousands and millions; the Ordnance Department builds single units when funds are available. Since the armistice we have built, not manufactured, a total of seven tanks. The engineer usually can evolve a good design; but, to gain that last few per cent that is so necessary to reliability, we must build and test; build and refine; build and perfect. If at times we and our "customers" become discouraged and feel that our progress is slow, let us not forget that we are working "under wraps."

Such remarkable progress has been made during the last decade, and is being made from year to year, in automotive design, that the engineer wonders at the retention of animal-drawn transportation in the Army. He feels that, with the enormous automotive production facilities in our Country, our Army should be in a most favored position. He knows that this is an age of motorization, or high-speed transportation, and he firmly believes that he has built and will continue to build such reliability and performance into his vehicles that the Army will motorize as business has done.

We shall still use the horse, but the motor will steadily circumscribe his usefulness.

The entry of the Ordnance Department into the field of automotive design dates from 1917. Shortly before then the artillery had tested a few commercial tractors; and a small number of armored cars, built on commercial truck chassis, had been produced experimentally for use with the cavalry. Let us see where we stand today.

WAR-TIME TANKS AMERICANIZED

At the time of our entry into the World War, the subject of tanks was an entirely new one to the Ordnance Department, and our war-time designs were largely British and French designs adapted to our manufacturing standards. The tanks thus produced were the Mark VIII, one of which is shown in Fig. 1, and the 6-ton Renault, shown in Fig. 2.

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[1] Chief of automotive section, office of Chief of Ordnance, War Department, City of Washington.

[2] S.M.S.A.E.—Chief of Ordnance, War Department, City of Washington.

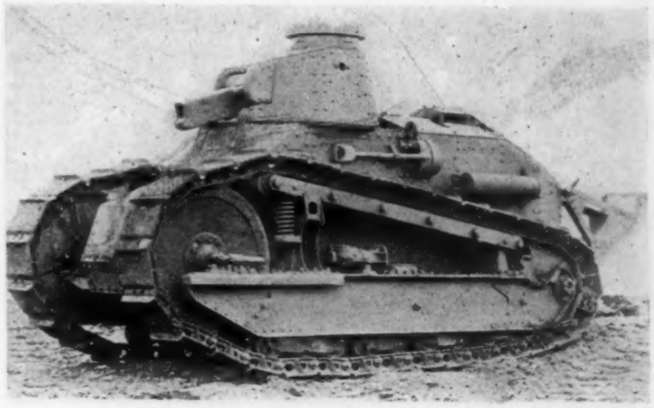


FIG. 2—RENAULT DESIGN 6-TON TANK

The Mark VIII, of which 100 were completed after the armistice, weighs 40 tons and is driven by a modified Liberty aircraft-engine at a speed of 5 m.p.h. A crew of 12 men operates the tank and mans two 6-pounder guns and seven machine-guns. The armor protection is from 6 to 16 mm. (0.236 to 0.730 in.) thick. The great length of the vehicle gives it maximum ability in crossing trenches. Its size, however, makes it an easy target and decreases its mobility. Speed is obviously one of the best protections a tank can have against hostile fire. The present trend of design is toward lighter and much faster tanks.

The 6-ton Renault tank was produced in large numbers in this Country for use in the World War. It falls short of meeting the requirements for a light tank, for it is mechanically unreliable and its speed is only 6 m.p.h. The crew, protected by armor that varies in thickness from 0.25 to 0.60 in., is composed of a driver and a gunner. The armament, either a 37-mm. (1.457-in.) gun or a caliber-0.30 machine-gun, is mounted in a turret that has a 360-deg. traverse.

The Ford two-man tank, shown in Fig. 3, represents one of many attempts that the Ordnance Department made during the war to collaborate with commercial industry in the production of tanks. A few of these were built during the war, but the armistice was declared before quantity production was inaugurated.

The experience with these tanks of three types emphasizes the fact that mechanical reliability results only from designs that have been carefully thought out and perfected later, after tests. Each of these tanks is a remarkably good product, when we consider that it was designed during the stress and hurry of war, and that little or no development and test work were done before quantity production was begun.

After the armistice, General Pershing appointed a board of officers, now known as the Caliber Board, for the purpose of recommending ideal types of Army ordnance equipment on which development work should proceed. One of the recommendations of the board was for the development of a medium-weight high-speed tank.

The 23-ton tank, Model T1, shown in Fig. 4, which is now undergoing test by the Tank Board, is the third of this type built and incorporates the improvements found necessary in the tests of the first two. The speed is 12 m.p.h.; the armor is 1 in. thick over the fighting compartment; and the armament is one 6-pounder gun and one caliber-0.30 machine-gun in the lower turret, with one caliber-0.30 machine-gun in the upper turret. The crew consists of a driver, a gunner, a loader, and a tank commander, who also fires the upper machine-gun. This tank is mechanically good and appears to be well received by the Tank Corps.

We feel, however, that we can produce a tank of 12 to 15-ton weight having equal or greater fire power. This vehicle would be much "quicker on its feet" and would present a much smaller target. Trench-crossing ability is a function of length; but more length means more weight, and more weight means more engine power; which calls for a repetition of the vicious cycle, beginning again with more weight. It is obviously impossible to armor against all calibers of guns unless we build "land battleships," such as may make their appearance in any protracted situation of stabilized combat, which might conceivably carry large numbers of machine-gunners to occupy the ground gained. Thus, all design is of necessity a compromise of factors desirable and undesirable. We feel that we should constantly strive for speed and fire power, with the maximum armor protection consistent with reasonable weight.

The most interesting tank we have is the light tank T1E1, shown in Fig. 5. An experimental model has

FIG. 1—MARK-VIII TANK, A WAR-TIME DESIGN

FIG. 3—WAR-TIME FORD TANK

been completed and given an extensive test of 1500 miles. Such a distance represents a long war. Its remarkable mechanical performance has resulted in an enthusiastic reception of the "job." Its fire power is the maximum obtainable in a vehicle of that weight. The rated speed is 18 m.p.h., and the cruising radius on the gasoline carried is 80 miles. Gradients of 45 deg. have been ascended. (See Fig. 6.) The crew, consisting of a driver and a gunner, is protected against the service-rifle bullet at all ranges. In the all-round-fire turret are mounted both a 37-mm. (1.457-in.) gun and a caliber-0.30 machine-gun, with a fully adequate supply of ammunition. The mount for the guns provides for a limited traverse independent of the turret traverse, and for ample depression and elevation. The fighting compartment is completely ventilated; the first time such comfort has been provided for the personnel. The mechanical control and operation are of the simplest. The commercial Cunningham engine provides ample power for any kind of terrain. The speed of tanks over rough ground depends largely on the ability of the crew to stand punishment.

Four more tanks of this model, incorporating changes found desirable, have just been completed for

FIG. 4—POST-WAR 23-TON TANK T1
The Plumb-Bob Shows the Angle. Help Was Required by the Tank in Crossing This Trench

the Ordnance Department by James Cunningham, Son & Co., of Rochester, N. Y., and are now undergoing test by the Service so that we may have the advantage of suggestions and helpful criticism in this development. In the test of these vehicles, held at the plant, the performance exceeded our highest expectations.

The type of suspension designed for this tank by our chief automotive engineer, H. A. Knox, represents a decided forward step, in that practically all of the rebound from operating over rough ground is eliminated. The importance of this feature as affecting the accuracy of fire from the tank is obvious. The design of track eliminates much of the objectionable noise met with in high-speed track-laying vehicles. The vehicles are rugged and simple throughout, and tests to date indicate that maintenance will present but a small problem. As soon as funds can be secured, at least a battalion of 72 of these light tanks should be placed in the service for tactical tests; as, obviously, much will have to be worked out in the correct employment of these high-speed, high-fire-power little machines.

One of the most interesting features in the design of the light tank T1E1 is that it is built on a basic all-purpose chassis that may be likened to an automobile chassis on which can be mounted several different styles of body. One of the service demands that has been most perplexing to us is that for a cargo carrier to follow the tanks with oil, gas, water, spare parts, tools and the like. It was to meet this very real requirement, and to hold to the minimum the number of special vehicles to be produced in war, that the all-purpose chassis was evolved.

CHASSIS ADAPTABLE TO CARGO CARRYING

Fig. 7 shows the chassis with tank superstructure replaced by a cargo body of from 2 to 3-ton capacity. This body may be of a wide variety of types. We have in mind a platform body for mounting large wire-reels for the Signal Corps, a similar body to carry a balloon-winch for the Air Corps, a stake body for engineer equipment, a tank body for water and gasoline, a light armored body for carrying personnel, and other types. As a light, fast tractor for loads up to 6 tons, this unit is without a peer today. The chassis is truly an all-purpose one, and it is a good production design with a greatly simplified maintenance as regards spare and replacement parts for the field. Even so, it represents only a good start. Much remains to be done to perfect the vehicle, and we need not only funds but the test of service use of a number of these tanks.

One of our dreams of several years' standing, in which the British have "scooped" us, is the design of a light, fast and small armored conveyance for getting an individual over a fire-swept zone with some protection other than his skin, and having a machine-gun, which is the means for maximum fire-power. This conveyance, call it tank or whatever you will, will carry but one man, who will drive with his feet and thus have his hands free to operate the gun. If he should wish to leave the vehicle, a pull on a pin releases the machine-gun, which he then can set up on its tripod. This little tank will present only a small target, its speed will be high, and we shall at last have a highly mobile armored machine-gun.

If we are successful in working out a satisfactory light-weight suspension and track for such a vehicle, it is very probable that the same chassis can be used

also as an infantry carrier. After a tank attack has gained ground to the front, it is of course necessary, in order to hold the ground, to occupy it with machine-gunners and automatic-rifle men. These little carriers will conceivably carry three or four men, with their machine-guns and ammunition, and will move forward rapidly to the line with the personnel protected by light armor-plate.

We may expect war-time losses in tanks to be high; but, if a wise policy has given us enough of these machines, they will accomplish their mission. It is possible that the losses may not be so great, for the Chemical Warfare Service has recently evolved a smoke-producing apparatus for the tanks which may find favor with the infantry. The use of tanks will enormously reduce battle losses, and their early and continued employment will assure a war of movement to the side that has them in quantities.

Cross-Country Vehicles

Our first efforts to produce a fast vehicle for reconnaissance work resulted in a Ford car with two additional dead axles and a fabric-belt track over and around all wheels. It would cross almost anything, but its life was woefully short, due to additional tractive resistance. We also tried several special designs of our own with but indifferent success.

The latest type of cross-country car is a standard Chevrolet or Ford chassis[3], equipped with oversize balloon tires and light bucket seats. Some of us feel that the car has become too heavy for best results, and it is in our minds to try to bring the weight down nearer to that of the original car which we produced in 1923.

The purposes of the light cross-country car are partly to supplement the motorcycle, to carry reconnaissance parties, and to supplement the horse and replace him where possible. A small box or a wire reel can be substituted for the rear seats. The performance of the cars across country and soft ground is excellent, and their reliability needs no comment.

[3]See The Journal, July, 1928, p. 98.

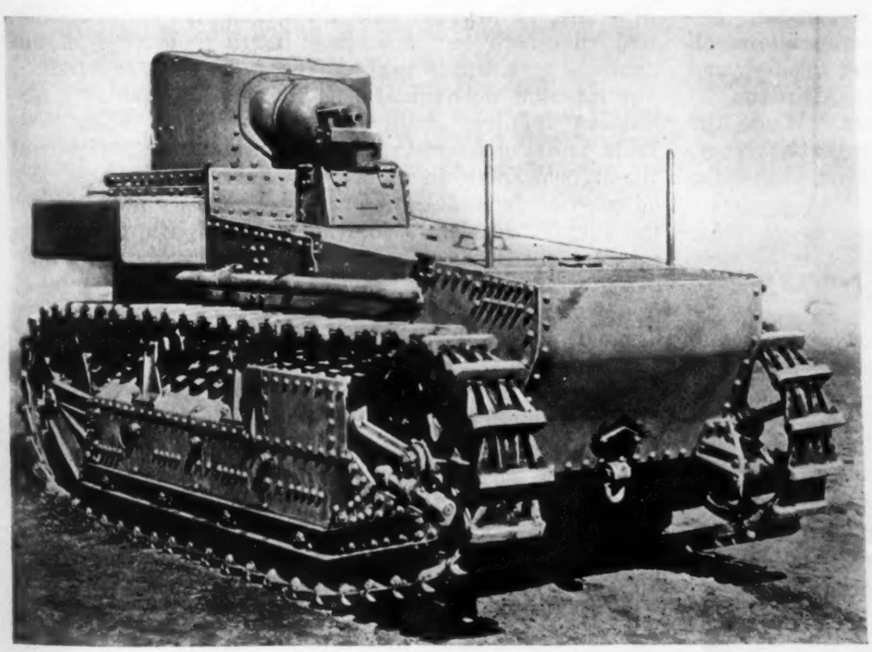


Fig. 5—The Latest Light Tank T1E1

Fig. 6—T1E1 Tank on a 45-Per Cent Grade

Among the cross-country cargo-carriers are several different types of vehicle: trucks, trailers, self-propelled cargo-carriers, and power carts.

The ability of any vehicle to move over soft ground is primarily a function of unit ground-pressure and varies inversely therewith. Other factors, such as ground clearance and gear reduction, enter, but unit ground-pressure is paramount.

The standard Chevrolet 1-ton truck has been equipped with balloon tires and an extra driven-axle, with the idea of lessening the unit ground-pressure and increasing "mud ability." The additional axle adds but little complication of design and delay in production. The body is of our own design, and comfortably seats five men on each side or carries a load up to the rated capacity of the chassis. One of these trucks is seen in Fig. 8.

For cross-country work a light truck is much better than a heavy one, because a squad of men can extricate it fairly easily if necessary. Heavy trucks that must stick to the roads can operate to "truck heads," as trains operate to rail heads, from which the light trucks or track-laying cargo-carriers can operate.

It should be accepted as axiomatic that no round-wheel vehicle is equal to one of the track-laying type in negotiating bad going; the round wheeler, on the other hand, is much more mobile on roads and hard ground, its mileage life is much greater, and the maintenance problem is far simpler. It is known that the truck is more of a "fair-weather sailor" than the track machine, but only by a service test under field conditions can the Army determine the proper uses of each in our organization.

Several different types of track adapter for use on heavy trucks have been tested at our proving ground within the last six years. A typical example of these is the 5-ton Mack truck with its rear wheels replaced by a Christie track-mechanism. Forgetting for the moment the relatively short life of any adapter so far tested by us at speeds considered necessary by the Army, the important and in-

surmountable fact remains that the truck is designed to drive a round wheel, not a track mechanism with its greatly increased tractive-resistance. In other words, to drive a track-laying machine, the engine and power-transmission units must be built for that purpose, or failure results.

I believe we have overlooked nothing in our efforts to test all promising ideas, whether presented in this Country or abroad. Adapters with steel tracks, wire tracks, fabric tracks, and rubber tracks have had a full and impartial trial.

Several types of track-laying trailer have been built and tested, but the trend is decidedly toward the wheeled vehicle. The complications of a track mechanism and its limited road mobility outweigh its advantages for cross-country operation. Probably the ideal trailer has wheels and a smooth underbody for sledding in deep mud. If it is towed by a tractor of proper power, it will perform up to any reasonable expectation or demand. Many excellent wheeled-trailers are available in the commercial market. With relatively minor modifications they will meet adequately the severe requirements of the military service.

A few self-propelled track-laying cargo-carriers have been built and tested. Though underpowered, they were fairly successful and served to prove the entire practicability of the idea. The light cargo-carrier on the all-purpose light-tank chassis will, we feel, fully meet the requirements for this class of transport.

In our next design of a medium tank, we shall try to provide a chassis for the carrying of greater loads, probably 6 to 7 tons. This heavier vehicle will have an equally wide range of useful service as the light cargo-carrier.

The Caliber Board evolved the idea of a light-weight power-driven cart, able to operate over soft ground, to have a pay-load rating of 450 lb. Several were built, of the track-laying type, but the exacting limitations in weight to permit "manhandling" made it impossible to build the necessary mileage-life into them. Next came a four-wheel-drive balloon-tired cart, driven by an air-cooled motorcycle-engine at a speed of 4½ m.p.h. Articulation between the front and rear axles allows all the wheels to follow inequalities of the ground and gives excellent tractive ability. Steering is done by varying the angle between the two axles. While the performance of this model has been fairly satisfactory, the thought is now that we should endeavor to develop a light armored track-laying vehicle capable of transporting three men, with a Browning machine-gun and necessary ammunition, for advancing across fire-swept areas. Such a vehicle will no doubt be far more effective in reducing battle losses than the wheeled power-cart just described.

FIG. 7—CARGO-BODY ON T1E1 TANK-CHASSIS

FIG. 8—CHEVROLET 1-TON TRUCK REMODELED WITH SIX WHEELS

TRACTORS OF COMMERCIAL MANUFACTURE ARE BEST

As is rather generally known, the Ordnance Department, working in collaboration with a commercial manufacturer during the war, designed the 5 and 10-ton tractors, Model 1917, of which large numbers were built for towing Corps and Army artillery, respectively. It is of particular interest to know that, even though the 5-ton tractor was designed and built in only seven weeks, none of the vehicles reached France until the summer of 1918. From the building of a pilot model to quantity production is a long step.

The Caliber Board recommended the development of fast tractors for the Division, the Corps and the Army. During the three years following the armistice, satisfactory types for each were developed and the drawings are available.

In connection with the design of special vehicles, the Army always is faced with the problem of keeping them uptodate. Funds for this are seldom, if ever, available, and therefore our machines become obsolete in mechanical type and in performance. The delay of putting any sizeable mechanical construction into quantity production requires little elaboration here. With these facts and the heart-breaking production experience of the World War in mind, the wise policy has been adopted of depending upon the commercial industry for the supply of tractors for the Army. While these tractors are not in all respects ideal for military uses, competition assures that they always represent the latest in the automotive art. In time of emergency, factory production can be augmented to meet our schedule of requirements. Each year, as funds make it possible, the department tests a few tractors so that we can keep fully informed as to available and suitable types. This applies to both track-laying vehicles and wheeled vehicles such as the Fordson, McCormick-Deering, and Topp-Stewart.

Various track adapters and "trick" wheels have been tried out with wheeled tractors. A test has been made also of at least one foreign-made tractor. In addition, tractors are being brought to our attention constantly that are found to be unsuited to our service and which therefore do not reach our proving ground.

Our standard tractors are now the Caterpillar 2-ton,

the Caterpillar 20, the 5-ton Caterpillar 30, and the 10-ton Caterpillar 60. Under military service-conditions, each of the tractors will satisfactorily handle loads equal to its own weight. They can also be double-headed. The rate of march is about 4 m.p.h., but it can be increased to 8 m.p.h. by substituting high-speed gears. Such speeding-up of units not especially designed for high speed results in materially shorter mileage-life.

Motor Carriages for Guns

A motor carriage is, in effect, a high-speed track-laying tractor that mounts a gun or howitzer for transport and firing. Highly satisfactory types have been brought out for Division, Corps and Army use; but this line of endeavor is now lying dormant, largely because of lack of funds. We feel, however, that the motor carriage has a future and that some day it will come into its own. The thought of moving a Division gun across country at 15 m.p.h. or a Corps or Army gun at 10 m.p.h., and emplacing any one of them in less time than it takes to determine the firing data, is most alluring.

Of particular interest is the Division motor-carriage, shown in Fig. 9, mounting the 75-mm. (2.953-in.) gun. The motive power is a Cadillac motor-car engine, which gives a high speed of 15 m.p.h. In putting the vehicle into firing position, the brakes are set, the outriggers or struts at the rear are lowered to the ground quickly by pulling a pin, and the mount is ready. This unit, provided with suitable armored shields, is of use as an accompanying gun in an advance and also provides a highly mobile unit as an artillery reserve.

In spite of all of the old arguments, such as that the gun is useless if the tractor breaks down and the tractor stands idle while the gun is in place, I dare the prediction that the motor carriage eventually will have its place in our organization. Ammunition will be supplied by the light cross-country cargo-carriers operating at the speed of the motor carriage.

A committee of eminent engineers of the Society of Automotive Engineers has, since 1919, been of inestimable value to us. All of our automotive projects have been submitted to its members at biannual meetings, held usually at some great plant of the industry. We have received constructive criticism and helpful advice, and have been given access to the latest developments in the art. We give grateful acknowledgment to this group of patriotic citizens who serve us entirely without remuneration. It is a pleasure to list the names of the following well-known members of the Society who have served us on this committee: H. W. Alden, B. B. Bachman, W. L. Batt, David Beecroft, C. F. Clarkson, G. W. Dunham, George A. Green, A. W. Herrington, P. E. Holt, C. F. Kettering, A. F. Masury, Dent Parrett, D. G. Roos, G. A. Round, William Turnbull, W. G. Wall, and the late C. M. Manly. We have been fortunate also in the type of the automotive engineers who came into our service during the war, some of the best of whom have remained.

No one can fail to realize that we are in an age of mechanical transportation. All commercial industry is adopting motor transport in ever-increasing proportion. Our reports from abroad indicate that other armies are tending much more strongly than we toward motorization. This Country possesses an automotive industry greater by far than that of all the rest of the world combined, and our Army must and will take full advantage of our favored position.

Motorization Will Involve Reorganization

The Ordnance Department and various Service boards have made complete mechanical and performance-tests of many motor-vehicles. As new models come out, they will be similarly tested. Enough data have been accumulated, and it is now in order to take the logical next step. Motorization, or mechanization, as we call it, involves much more than merely putting a tractor in the place of a team of mules, or a truck in place of an escort wagon. It involves working out an organization built around motor transport; an organization that has great mobility; an organization that has fewer men. Mass is the foe of mobility. In short, we shall be obliged eventually to work out a complete reorganization based upon modern transportation-methods, in order to fully realize their advantages.

Further mechanical tests of one or two machines will serve no such purpose; motorization now is a problem for the combatant branches. With this end in view, the Secretary of War ordered the assembly of a small force of all arms, equipped entirely with motor transportation, at Fort Leonard Wood, Maryland, during the summer of this year. The unfortunate fact that much of the equipment is of war-time design will preclude obtaining a correct picture of the capabilities of such a force equipped with modern vehicles. However, it is a start in the direction of working out suitable tactics for the employment of a motorized force in its proper relation to the organization of the Army; and, when funds are available for the acquirement of new equipment, the full possibilities of such a force will become apparent.

The vehicles described in this article represent types only. In every case the laborious work of reaching production remains for the future. Financial considerations make it impossible, in time of peace, to manufacture and store large quantities of such equipment, as it would soon become obsolete. What we hope, however, is that funds will be made available so that experimental and development work can continue, to enable us to keep abreast of the art.

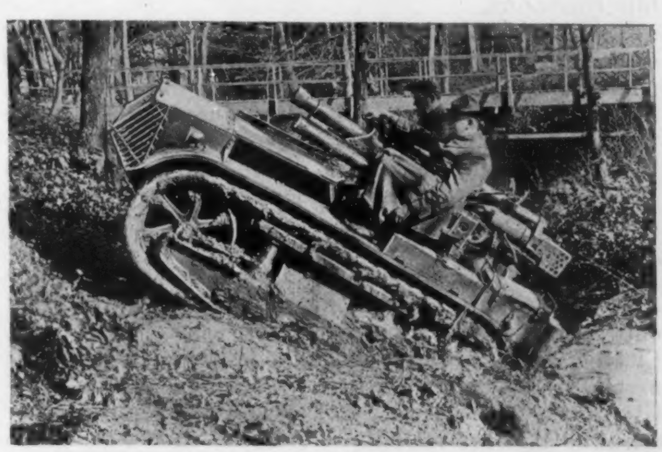


Fig. 9—Divisional Motor-Carriage Mounting 75-Mm. Gun

Automobile Practice in Europe

By Maurice Platt[1]

Semi-Annual Meeting Paper — *Illustrated with* Photographs, Drawings and Charts

EUROPEAN trends in some of the major features of engine, chassis and body design and in several items of equipment are reviewed in this paper; which is based on the observation and analysis of the British engineer editor who is its author, and of the staff of *The Motor*, of London, during the last five years.

Although American automotive engineers who follow European practice are acquainted with most of the designs here shown and described briefly, this paper is of interest and value as showing the present principal lines along which development is taking place abroad.

Popular chassis types are divided into three classes: (*a*) the "baby" four-cylinder car of 7 to 9 hp., Royal Automobile Club rating; (*b*) the "family-type" four-cylinder car of 12 to 14-hp. rating; and (*c*) the light six-cylinder car of 15 to 20-hp. rating. Typical acceleration curves for well-known cars in each of these classes are given, as well as cylinder dimensions, volumetric capacity, car weight and price. Other prominent car types of the larger size are dealt with in a similar way.

By means of graphs and tables, the trends over the last five years are shown in number of engine cylinders, valve arrangement, ignition, cooling, braking systems, transmissions, drive, spring suspension and wheels. Major new developments include front-wheel drive, independently sprung wheels, free-wheels and supercharging.

Trends in body design are indicated in regard to fabric bodies, three-point support, convertible bodies, and ways of securing a close-to-the-road appearance.

IN projecting this paper the somewhat ambitious aim was to present a broad view of automobile practice in Europe as it exists today, with an indication of the trends which design is following and whither they may lead. It was felt that within the compass of a relatively short paper sufficient could be included to give the American engineer some sort of general picture of European practice, as viewed through the eyes of a technical journalist having an engineer's training. There are bound to be omissions, but an endeavor has been made to base the selection on what is likely to be of most interest to the American engineer. Consequently it is hoped that this paper, despite its limitations, will serve a useful purpose in presenting a collection of current facts, opinions and data which ordinarily are only to be found scattered through the motoring and engineering journals or the proceedings of European bodies such as the Institution of Automobile Engineers.

The paper is divided into four sections: (1) Popular Chassis Types Classified, with particulars of design and performance; (2) Principal Trends in Chassis Design, illustrated by graphs plotted from annual analyses extending over five years; (3) Developments in Body-Work and Equipment; and (4) Chassis Changes in Prospect, not yet generally adopted.

1—POPULAR CHASSIS TYPES CLASSIFIED

In taking a broad view of European car design the American engineer should keep in mind the fact that only a relatively few concerns such as Morris, Austin, Citroen, Renault and Fiat are manufacturing cars at a rate of 1000 per week and upward and employ quantity-production methods. A large number of other concerns that are making automobiles in smaller quantities exist mainly because there is always a market for a car that is different, and in certain ways better, than its lower-priced competitors. These smaller concerns are better able than are the mass producers to alter their products at frequent intervals to keep pace with the latest fashions and theories. From them first come cars with novel features, such as superchargers, front-wheel drives, and free-wheel transmissions, as described in the fourth section of this paper. Through them considerable impetus is given to mechanical developments and changes in body-work fashions.

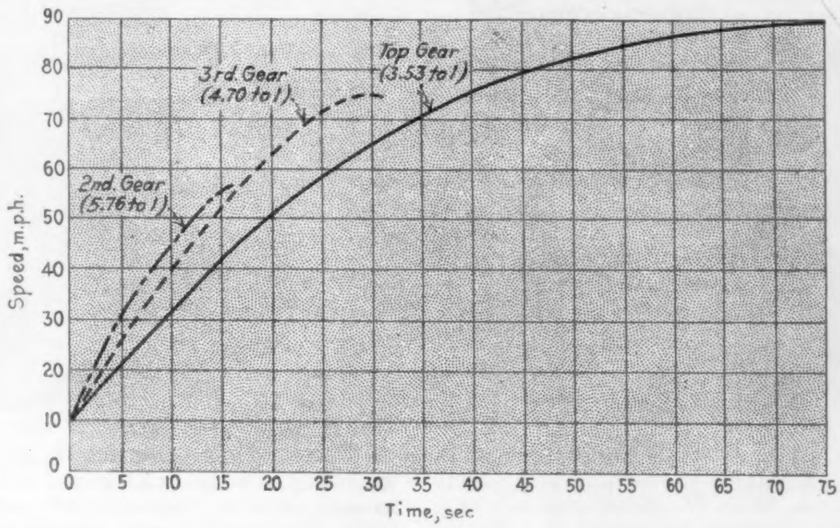
Another factor having a pronounced influence upon European design is the heavy taxation on automobiles, based on rated horsepower, fuel consumption, or both. This has led to the very thorough development of small four-cylinder cars, designed for economy in running, which have no counterpart in America. During the last few years, however, there has been a rapidly growing market for medium-priced six-cylinder cars; but here again the need for economy in running and a low tax has resulted in the development of relatively small engines having a high power-output from a given cylinder-capacity. Approximately 52 b.hp. is the output often extracted from a 2½-liter (152.55-cu. in.) "six" nowadays.

In obtaining a high power-output per liter (61.02 cu. in.) capacity—about 20 b.hp. for private passenger-car engines—the European designer is assisted by the excellence of the fuel generally available. By using overhead valves and machined combustion-chambers of small size, he can employ a high compression-ratio and high mean-effective-pressure. It is a great mistake to suppose that there is a wide discrepancy in the average engine-speeds employed in Europe and America. Last year the author analyzed the specifications of 75 well-known popular cars, selecting 25 each of American, British and Continental manufacture. The results are given in Table 1, from which it will be seen that, by chance, the engine speeds are identical for American and Continental cars, while the British engine-speed is about 7 per cent higher.

[1] Chief technical editorial representative, *The Motor*, London, England.

European cars that are achieving the largest sales fall into three main types: (*a*) the "baby" four-cylinder car of 7-9 rated hp., (*b*) the "family-type" four-cylinder car of 12-14 hp., and (*c*) the light six-cylinder car of 15-20 hp. Leading particulars of these are given in Table 2, in which the cruising speed is that which can be maintained in comfort by the average driver on good main roads without "tiring" the engine, an unscientific term but one, nevertheless, that is self-explanatory.

The performance of these and other types of European car is illustrated by Fig. 1, in which are shown acceleration curves for certain well-known makes. These curves have been plotted in speed against time from figures obtained by members of the editorial staff of *The Motor* when road-testing these cars, and are all of recent date. Prior to carrying out the tests, the speedometer of the



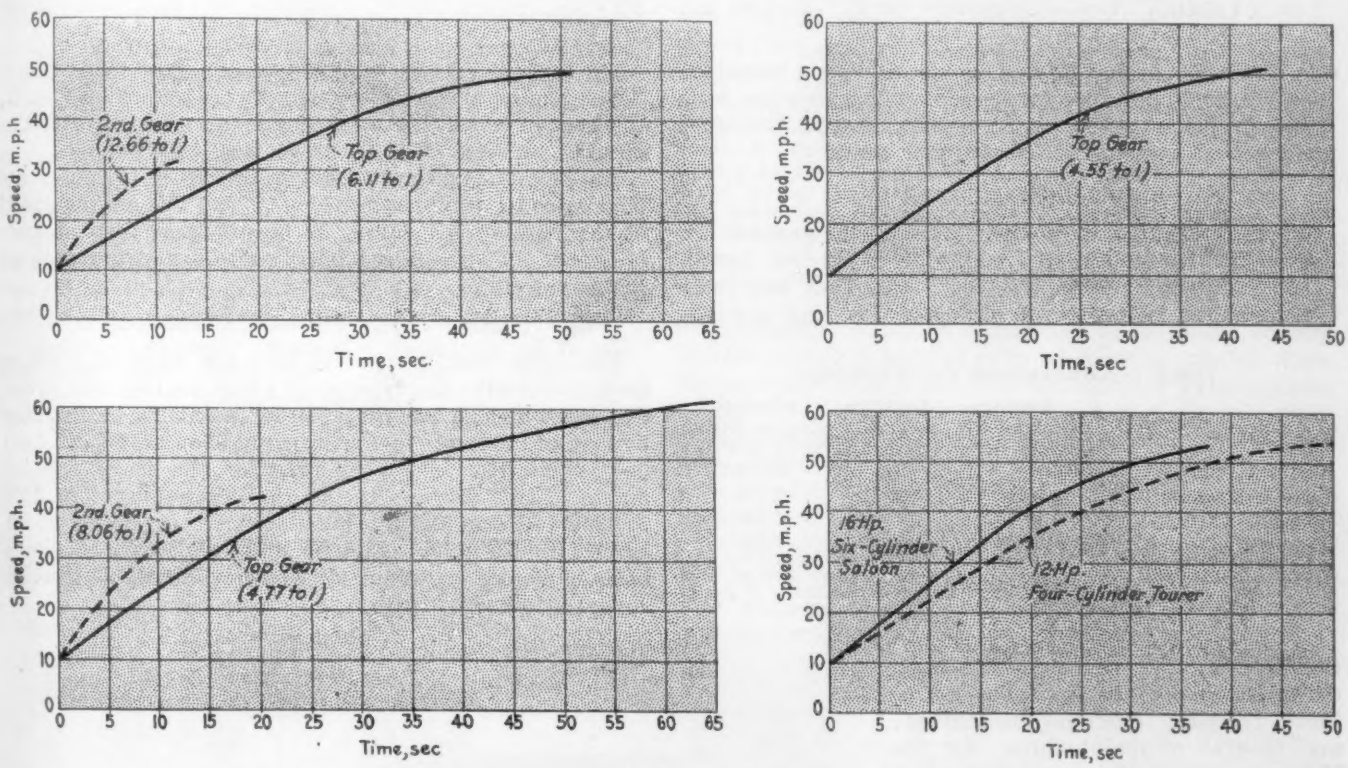


FIG. 1—ACCELERATION CURVES FOR TYPICAL BRITISH AND CONTINENTAL CARS

(Top) From a Typical High-Grade Sports Car, the Four-Cylinder British Bentley. Cylinder Dimensions, 100 x 140 Mm. (3.937 x 5.512 In.). Volumetric Capacity, 4398 Cc. (268.367 Cu. In.). Horsepower, R.A.C. Rating 24.8. Weight, as Tested, 35 Cwt. (3920 Lb.). Price, £1,250 ($6,100). The Curves Are for Acceleration on a Dry Concrete Road

(Upper Left) From Typical "Baby" Four-Cylinder Car, the 9-Hp. Italian Fiat Saloon. Cylinder Dimensions, 57 x 97 Mm. (2.244 x 3.819 In.). Volumetric Capacity, 990 Cc. (60.41 Cu. In.). Horsepower, R.A.C. Rating, 8. Weight, as Tested, 19½ Cwt. (2184 Lb.). Price, £225 ($1,098). The Curves Are for Acceleration on a Dry Concrete Road

(Lower Left) From a Typical Light-Six Car, the British Morris Saloon. Cylinder Dimensions, 69 x 110 Mm. (2.716 x 4.331 In.). Volumetric Capacity, 2468 Cc. (150.60 Cu. In.). Horsepower, R.A.C. Rating, 17.7. Weight, as Tested, 31 Cwt. (3472 Lb.). Price, £395 ($1,927.60). The Curves Are for Acceleration on a Dry Macadam Road

(Upper Right) From Typical "Family-Type" Four-Cylinder Car, the British Singer-Senior Fabric Saloon. Cylinder Dimensions, 69 x 105 Mm. (2.716 x 4.134 In.). Volumetric Capacity, 1571 Cc. (95.86 Cu. In.). Horsepower, R.A.C. Rating, 11.9. Weight, as Tested, 24½ Cwt. (2744 Lb.). Price, £250 ($1,220). The Curve Is for Acceleration on a Wet Tarmac Road

(Lower Right) Comparative Acceleration Curves from British Austin Four and Six-Cylinder Models, Typical of the Improved Performance Being Obtained by Many Makers Who Are Replacing a Four-Cylinder Engine by a Slightly Larger Six in the Same Chassis. Details of the Two Cars Are Given in the Text. The Curves Are for Acceleration on a Dry Concrete Road

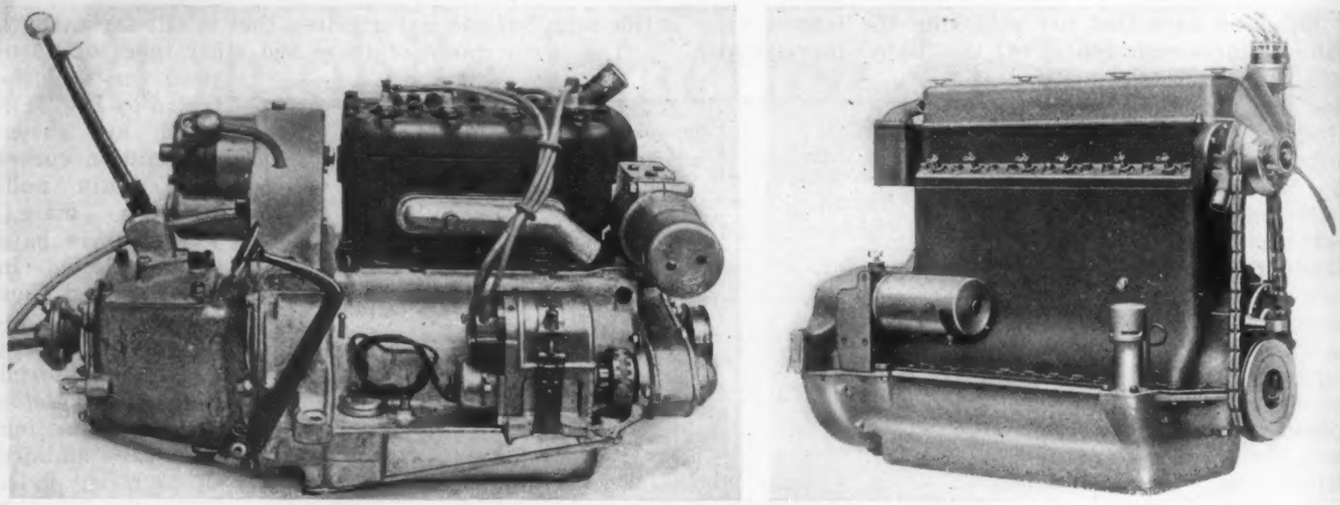


FIG. 2—EXAMPLES OF BRITISH FOUR AND SIX-CYLINDER ENGINES

(Left) "Baby" Four-Cylinder-Engine and Transmission Unit of the Austin "Seven" Small Car, Which Weighs 8½ Cwt. (952 Lb.), Empty, in the Open Model. Cylinder Dimensions, 56 x 76 Mm. (2.205 x 2.992 In.). Volumetric Capacity, 747 Cc. (45.58 Cu. In.)

(Right) New 2-Liter Six-Cylinder Rover Engine, an Excellent Example of Clean Design. Weight of the Rover Fabric-Saloon Model, 25 Cwt. (2800 Lb.), Empty. Cylinder Dimensions, 65 x 101.6 Mm. (2.559 x 3.979 In.). Capacity, 2033 Cc. (123.44 Cu. In.)

car is always checked at various speeds over a measured distance, and allowance for speedometer errors has been made in plotting the results. The graphs therefore show actual speeds, not speedometer readings.

"BABY" FOUR-CYLINDER CARS

These diminutive cars with four-cylinder engines are exemplified by well-known makes, such as the Austin 7-hp., the Peugeot 9-hp., and the Fiat. They owe their popularity to low costs of purchase, tax and upkeep; the facility with which they can be driven or parked in towns, owing to their compact over-all dimensions; and to ease of maintenance, for the European owner-driver still does a great deal of maintenance work himself. Accommodation for four persons is almost invariably provided, although the space available for two of them may be cramped. Saloon and open bodies are roughly equal in popularity, and the equipment is almost as complete as that of large cars. It is of interest to note how extraordinarily durable these small chassis prove in hard service. The engine is usually of the side-by-side poppet-valve type, with a two-bearing crankshaft, and the transmission follows orthodox lines, usually with three forward speeds. As an example of the type, the Austin Seven engine and transmission unit is shown in Fig. 2; the capacity is 747 cc. (45.58 cu. in.) and the cylinder dimensions 56 x 76 mm. (2.20 x 2.99 in.).

TABLE 1—COMPARATIVE ENGINE-SPEEDS

Place of Origin	Average Axle-Ratio	Average Tire Diameter, In.	Calculated Engine-Speed at 20 M.P.H., R.P.M.
Great Britain	4.85 to 1	29½	1,105
America	4.78 to 1	31	1,030
Continent	4.68 to 1	30½	1,030

Note.—Figures in this table were obtained by averaging the specifications of 25 popular cars each of American, British and Continental make. Exceptional cars, such as the Model-T Ford, with its axle ratio of 3.63 to 1, were not taken into account.

The acceleration curves given in Fig. 1 for the 9-hp. Fiat saloon are typical for this class. The engine speed of the Fiat corresponding to 32 m.p.h. on second gear is nearly 5000 r.p.m., which is well beyond the peak of the power curve.

"FAMILY-TYPE" FOUR-CYLINDER CARS

The term "family-type" is used for want of a better term to describe the type of 12-14-hp.-rating four-cylinder car which is bought in great numbers in England by men of moderate means, earning about £500 ($2,440) per year. The saloon-car price of the more popular makes of this class on the British market is from £200 to £250 ($976 to $1,220), but there are also plenty of examples in the £300 ($1,464) class that compete on a basis of better workmanship and durability, distinctive appearance and so forth.

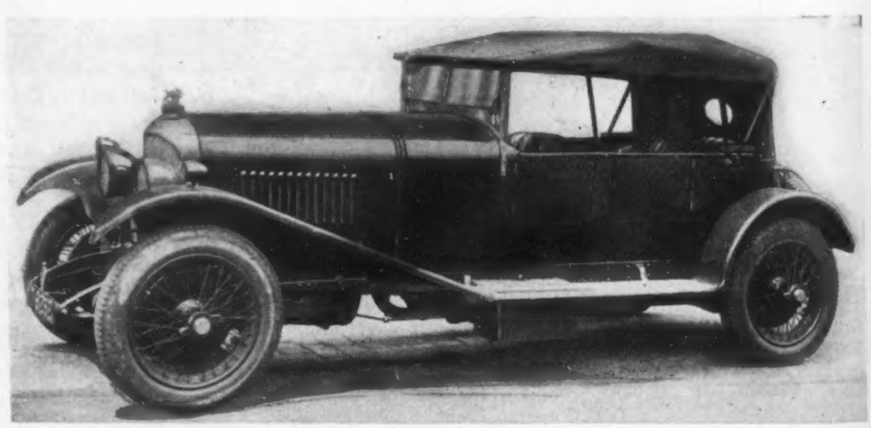


FIG. 3—TYPICAL HIGH-POWERED OPEN CAR POPULAR AMONG SPORTING OWNER DRIVERS

Bentley 4½-Liter (274.59-Cu. In.) Sports-Model, Designed To Have a Low, Speedy Appearance. With a Horsepower Rating of 24.8, This Has a Maximum Speed of 90 M.P.H. and Sells for £1,250 ($6,100)

The 12-14-hp. four-cylinder engine may have side-by-side or overhead valves, according to make and price; a three-bearing crankshaft; and magneto ignition. A three-speed transmission is provided in the car of the £200 type, but for the more expensive models four forward speeds are commonly employed. Other particulars are given in Table 2.

An acceleration curve that is typical of this type of four-cylinder car is that in Fig. 1 for the Singer Senior-Model fabric saloon. This car is fitted with an overhead-valve engine. Acceleration figures for the middle gear of the three-speed transmission were not taken, but the maximum speed on this ratio, 8.44 to 1, is 32 m.p.h.

Light Six-Cylinder Cars

Quantity production of light six-cylinder cars rated at 15 to 20 hp. and selling at moderate prices is a comparatively recent development in Europe, but virtually all the leading makers now are turning out cars of this class. Broadly speaking, the aim in producing these sixes is not to evolve a car with a greater carrying capacity but one which, while of much the same size as the 14-hp. four-cylinder type, is smoother, more flexible, and capable of better acceleration and higher maximum-speed. In many cases a factory is using the same chassis and range of bodies for both a 14-hp. four-cylinder model and a 16-hp. light six. An excellent example is found in the Austin, for which high-gear acceleration curves are given in Fig. 1 for the 13-hp. four and the 16-hp. six, the chassis of which are almost identical except for the engines.

The comparison is not altogether fair to the six, as the model tested was a saloon, whereas the other was a "tourer." The top-gear ratio is the same for each—5.18 to 1—and other particulars are as follows:

Bore Mm. (In.)	Stroke Mm. (In.)	Rating Hp.	Capacity Cc. (Cu.In.)	Weight Cwt. (Lb.)
		Four-Cylinder		
72 (2.83)	114.5 (4.50)	12.8	1,861 (103.55)	25 (2,800)
		Six-Cylinder		
65.5 (2.76)	111 (4.38)	15.9	2,249 (137.23)	27 (3,024)

In addition to these 16-hp. six-cylinder cars that have grown from four-cylinder models, there are many which represent new designs throughout. Here again the chassis and body dimensions do not differ very widely from those of previous 14-hp. four-cylinder cars of the same make. Most of these light six-cylinder engines come within capacity limits of 2000 and 2500 cc. (122.00 and 152.55 cu. in.) but the extreme limits of the class are 1½ and 3 liters (91.53 and 183.06 cu. in.). Overhead valves are the most popular, operated either by an overhead camshaft or push-rods, and the four-bearing and seven-bearing types of crankshaft are about equal

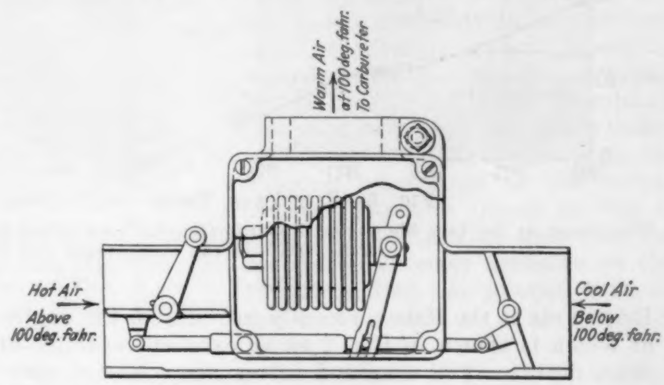


Fig. 5—Whatmough Automatic Control of Inlet-Air Temperature

This Experimental Device Is Designed To Overcome Trouble with the Mixture-Distribution System on New Six-Cylinder Engines. It Fits the Carbureter Inlet and Has an Open End for Admission of Cool Air and, on the Left, a Branch To Admit Hot Air from a Stove around the Exhaust Pipe. Both Branches Are Provided with Butterfly Valves, Connected with a Thermostat Which Regulates the Valve Openings Automatically According to the Temperature of the Air Passing Around It. A Temperature of 100 Deg. Fahr. Has Been Found To Give Good All-Round Results

in popularity. Opinion seems also to be fairly equally divided among designers as to whether to provide three forward speeds or four. The flexibility of a six-cylinder engine may be claimed to make a four-speed transmission unnecessary, but on the other hand its capacity for high revolutions makes the third gear of a four-speed transmission particularly useful for hill-climbing or acceleration.

Acceleration figures for a typical three-speed six, the new Morris, are graphed in Fig. 1. Another typical

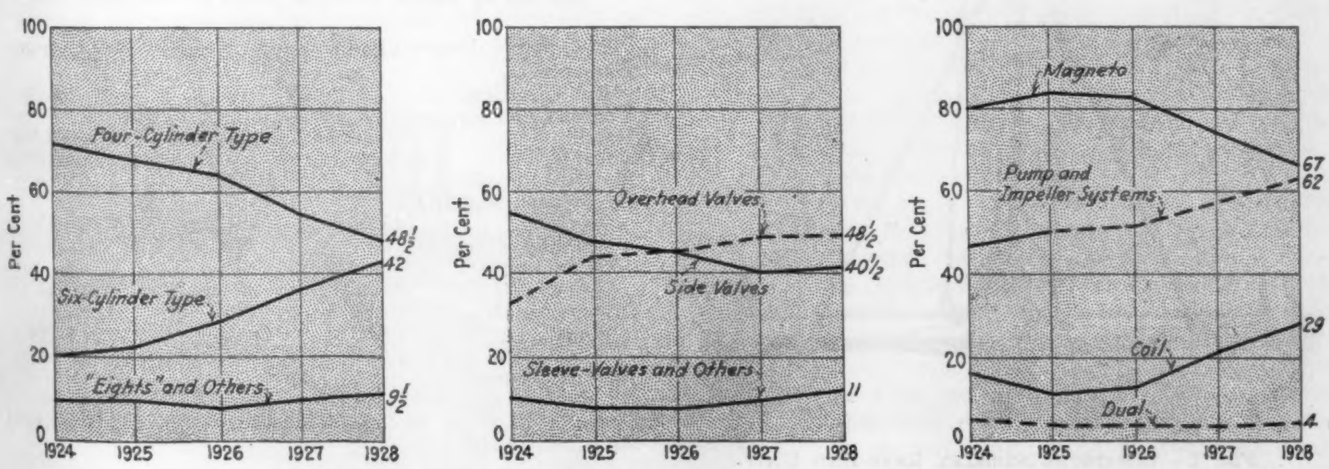


Fig. 4—Graphs of Engine Trend During Last 5 Years in About 300 Chassis

The Graph at the Left Shows the Trend in Number of Engine-Cylinders; That in the Center the Trend in Valves; and That at the Right the Trend in Ignition and Cooling. These Trends Are Not Strictly European, as Data for the Percentages Include Details from American and Canadian Cars Constituting 15 Per Cent of the Total of About 300 Individual Chassis-Models Available on the British Market. It Is Important To Bear in Mind that the Figures Are Not Based on Numbers of Chassis Sold

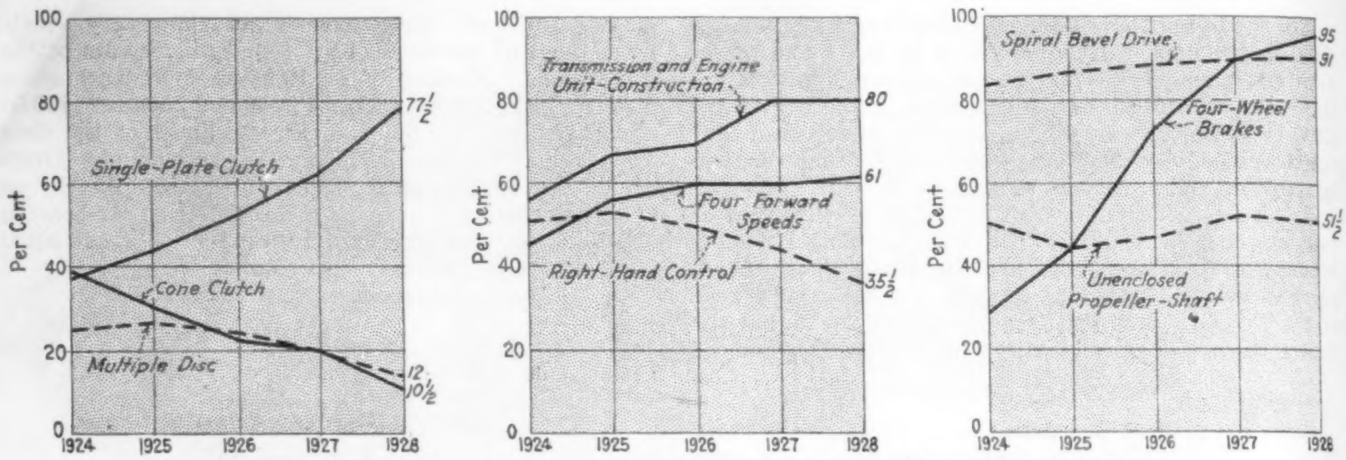


FIG. 6—FIVE-YEAR TREND IN CLUTCH, TRANSMISSION AND FINAL-DRIVE DESIGN

The Graph at the Left Shows the Trend in Clutch Types; That in the Center, in Transmissions; and That at the Right in Brakes and Drive. Data of the Percentages Are from the Same Source as Those in Fig. 4

British six is the Rover, recently introduced, the engine of which is shown in Fig. 2 as an excellent example of clean design. The overhead valves are push-rod operated.

Other Prominent Car Types

It is difficult to classify the large number of prominent European car types that remain. One that may be of particular interest to the American engineer is the sports-class car, ranging from the specially tuned four-cylinder 750-cc. (45.76-cu. in.) chassis to the 3-liter (183.06-cu. in.) six-cylinder car selling at £1,250 ($6,100) or more. These cars may be said to fill in the gap between the ordinary automobile and the racing car, some being merely tuned-up versions of the former, while others approach closely to the latter. A guaranteed speed of 70 m.p.h. is becoming rather common, and several sports models are guaranteed to reach 90 m.p.h. For the smaller types with four-cylinder engines of 1000 to 1500-cc. (61.02 to 67.53-cu. in.) capacity, several makers are using superchargers this year.

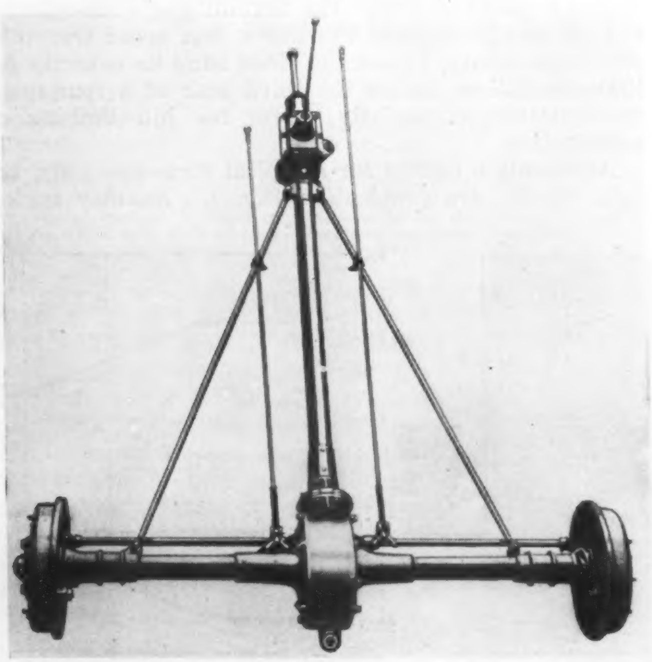


FIG. 7—ARMSTRONG-SIDDELEY REAR-END UNIT

This Is Representative of the Popular Transmission and Drive System for Chassis in Which the Transmission Is Separate from the Engine. The Front End of the Transmission Is Supported on a Frame Cross-Member, and the Propeller-Shaft Is Enclosed in a Torsion Tube

A leading example chosen to illustrate the capabilities of the British type of sports car is the 4½-liter (274.59-cu. in.) four-cylinder Bentley, shown in Fig. 3. This has an open body and is priced at £1,250 ($6,100). The acceleration curves are shown in Fig. 1. The maximum speed is 90 m.p.h. The bore and stroke are 100 and 140 mm. (3.94 and 5.51 in.) respectively, the horsepower rating is 24.8, and the weight with two persons is 35 cwt. (3920 lb.). The engine is fitted with two carbureters, four valves per cylinder, and an overhead camshaft.

There is a considerable range of six-cylinder chassis varying in rating and capacity from 20 to 30 hp. and 3 to 5 liters (183.06 to 305.10 cu. in.) and having wheelbases of from 130 to 138 in., so that a full-scale seven-

TABLE 2—MAIN PARTICULARS AND APPROXIMATE PERFORMANCE FIGURES OF THREE POPULAR TYPES OF EUROPEAN CAR

	"Baby" Four-Cylinder	"Family Type" Four-Cylinder	Light Six-Cylinder
Horsepower,			
R.A.C. Rating	7-9	12-14	15-20
Engine Capacity,			
Cc.	750-1,100	1,500-2,000	2,000-2,500
Cu. In.	(45.76-67.12)	(91.53-122.04)	(122.04-152.55)
Forward Speeds	3	Mostly 3	3 or 4
Road Speed, M.P.H.,			
Maximum	45-55	50-55	60-65
Cruising	40	40-45	45-50
On Indirect Gear	25-35	25-40	40-45
Dimensions, In.,			
Wheelbase	72-96	108-120	114-126
Tread	42-48	50-56	52-56
Weight, Empty,			
Cwt.	8½-18	20-27	24-28
Lb.	(952-2,016)	(2,240-3,024)	(2,688-3,136)
Miles per Gal. of Fuel,			
British	35-40	25-30	18-22
American	27-31	19-23	14-17
Price Range,			
Pounds	135-200	150-350	300-550
Dollars	(659-976)	(732-1,708)	(1,464-2,684)

passenger body can be carried. At the top of the class are well-known high-priced cars such as the 40 to 50-hp. Rolls-Royce, 45-hp. Renault and 37-hp. Hispaño-Suiza. At present the straight-eight engine is employed by only a few makers for the large, luxurious type of car, such as Isotta Fraschini, Panhard-Levassor, and Sunbeam, all of which have engines exceeding 5 liters (305.10 cu. in.) in capacity. Use of the straight-eight is, however, extending slowly. This year Ballot and Wolseley introduced 2½-liter (152.55-cu. in.) cars of this type, while straight-eight sports chassis are made by Alvis and Bugatti.

The largest private car built in Europe today is the British Daimler "double-six," which has a 12-cylinder V-type sleeve-valve engine having a capacity of 7136 cc. (435.44 cu. in.) and rated at 50 hp. The wheelbase and tread are 163 and 60 in. respectively, and the saloon model sells at £2,450 (\$11,956).

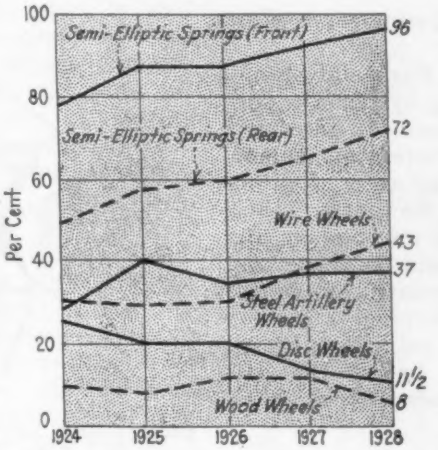


FIG. 8—TREND IN SPRINGS AND WHEELS

Data for the Percentages Are from the Same Source as Those in Figs. 4 and 5; Hence the Trend Is Not Strictly European

2—PRINCIPAL TRENDS IN CHASSIS DESIGN

Views expressed in this section of the paper are based mainly upon observations made by the author at the two great annual automobile exhibitions in London and Paris during the last five years and his various experiences with British and Continental cars and their makers during this period. To supplement these views, figures are quoted from analyses made by the staff of *The Motor* and published annually in that journal. The analyses cover the principal mechanical features of all the individual chassis-models available on the British market, about 300 in number. For 1928 these include 135 British cars, 75 French, 45 American and Canadian, 18 Italian, 15 German and Austrian, and 12 built in other countries.

The graphs used in this section to illustrate the trend of design from 1924 to 1928 are based on these annual analyses, but the figures are not strictly European, in view of the inclusion of American and Canadian cars constituting 15 per cent of the total. Consequently, the figures in Table 3 were prepared for this paper from current specifications of the 255 European chassis available in Great Britain. It is important to bear in mind that the graphs and table are based on the number of individual chassis analyzed and not on the numbers sold. From the table it will be seen that the chassis are fairly equally divided into four sizes in respect to engine capacity, and that the four-cylinder engine is still the most prominent type, followed by the six-cylinder engine at some distance. The increasing importance of the latter, however, is shown clearly by Fig. 4, from which it will be seen that the proportion of sixes available on the British market has jumped from 22 per cent in 1925 to 42 per cent in 1928.

Another striking development is found in braking systems. The almost universal use of four-wheel braking in Europe is well known; the graph at the right in Fig. 5 shows the five-year increase, from 30.5 to 95 per cent, in the proportion of four-wheel-braked chassis. But it may be news to some engineers that, of the 255 European chassis available in Britain, no fewer than 65, or 25.5 per cent, are provided with power servo-mechanism for brake application. During the last four or five years various prominent concerns, such as Rolls-Royce, Hispaño-Suiza, Renault, and Sunbeam, have been fitting frictional types of servo-mechanism, consisting of a multiple-disc clutch driven from the transmission shaft and operated by the brake pedal. The drag on the plates is utilized to apply torque to the clutch housing and so to operate the brakes. Such a system can be made to give excellent results but is complex and costly.

The present widespread use of power-assisted braking dates from the introduction of a vacuum-type servo-mechanism by M. Dewandre four years ago. The details of this mechanism and others of a similar type introduced later are so familiar that it will suffice to point out that it is not costly to make or install. It is part of the standard equipment of certain European cars priced as low as £220 (\$1,073.60). The only serious disadvantage of the suction-operated servo-mechanism is the sudden and considerable increase in pedal pressure required in case the engine stops.

In many ways the use of servo-braking has been beneficial; in others it has been harmful, because it has been used to cover up deficiencies in braking systems which would otherwise have made their existence felt by a necessary increase in pedal pressure; thus a servo-mechanism can be used to hide poor mechanical efficiency in the operating gear. General opinion seems now to be swinging round to the view that a power servo-mechanism should not be necessary on any car weighing less than 30 cwt. (3360 lb.), and a move has been made to simplify the operating mechanism by eliminating many pivot-points. Equalizers, for example, have been largely discarded. More

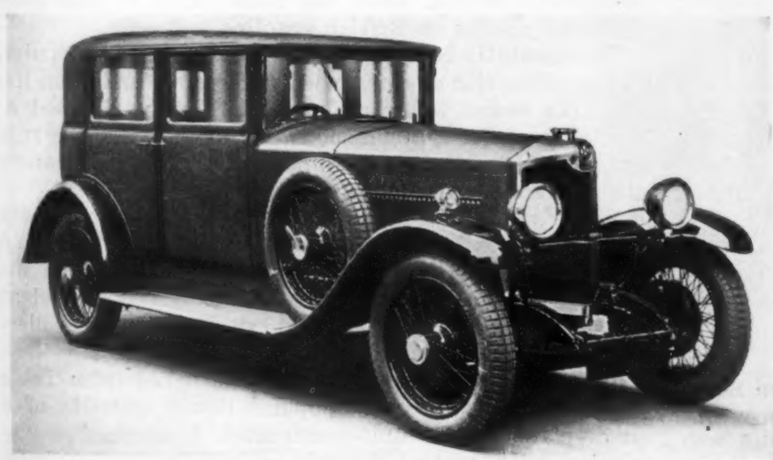


FIG. 9—EXAMPLE OF RIGID-TYPE FABRIC-COVERED BODY

This Body, Mounted on the Crossley Six-Cylinder 20-Hp. Chassis, Is Designated a "Four-Light Saloon"

interest is being shown in shoes possessing servo effect, such as the Perrot.

A chaotic state of affairs exists in Europe at present concerning the regulation of braking systems by law. Probably 80 per cent of European cars fail to comply with the strict letter of the law in respect of an independent braking system. The manufacturers of all but the more expensive cars seem to hold the opinion that a separate set of hand-operated shoes is unnecessary provided the hook-up of the hand-lever and pedal-operated system is arranged with the necessary safeguards against failure. It is not difficult to arrange a hook-up without equalizers in such a way that the failure of any rod or shaft cannot put more than two of the four brakes out of action, and the law needs to be modified to legalize such a system.

Easier Chassis-Lubrication

Next in importance are chassis changes designed to promote ease of maintenance, particularly with regard to the lubrication of minor chassis bearings, such as steering-gear connections, brake-gear pivots, and spring shackles. The first move, made about two years ago, was to group grease-gun nipples in batteries at convenient points, connecting them to the bearings by piping. Then the number of such bearings needing lubrication was cut down by the use of fabric shackles or pads of rubber composition for spring anchorages, but this practice did not extend very far. The principle, however, has been strongly revived in France and England by the Silentbloc bushing, a most ingenious device utilizing the properties of rubber in a state of strain.

A rubber sleeve is squeezed between inner and outer steel bushings so that it is extended longitudinally and compressed radially. This state of strain gives it a grip on the bushings and enables it to carry radial loads with very little deformation. The rubber sleeve, however, allows of considerable relative twisting between the inner and outer bushings without slip. This device therefore forms a silent bearing for spring ends and the like, where the movement required is small, and prolonged tests have shown it to be durable.

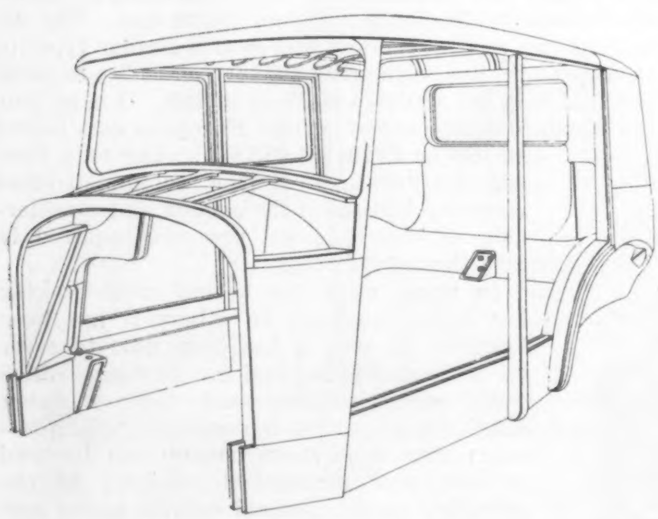


FIG. 10—SHELL OF THREE-POINT-SUSPENSION RIGID BODY

This Form of Construction Is Known as the Gordon-England System. The Wood Framing Is Rigid and Is Paneled with Three-Ply Wood, upon Which Cellulose-Coated Fabric Is Cemented. Two of the Hangers for the Three-Point Suspension Can Be Seen. Stiffness Is Secured by Means of the Box Section along the Bottom Edges, Which Extend Downward Outside the Chassis Frame. The Floor Is a Separate Unit

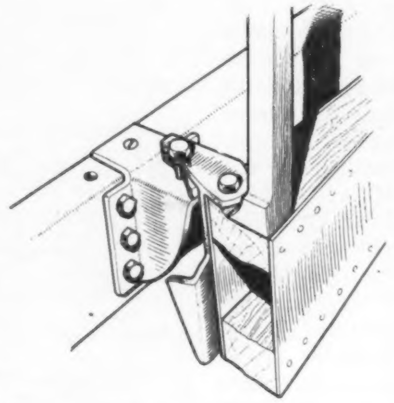


FIG. 11—SIDE ANCHORAGE OF RIGID-BODY FRAME

A Rubber Pad between the Steel Brackets on the Chassis Frame and the Body Sill Cushions and Silences the Body Shown in Fig. 10. Note How the Box Section of the Body Frame Extends Outside of and Below the Chassis Frame, Making a Valance Unnecessary

One-shot lubrication-systems, such as the Enots and Tecalemit, have been adopted to a certain extent, and I believe these are destined to become widely used in conjunction with bearings of the Silentbloc type which reduces the number of points to be served by the one-shot system.

The trend in engine design is shown by figures in Table 3 and Fig. 4. Overhead valves predominate, while side valves are used on one-third of the European chassis. Sleeve valves are making but slow progress. Many of the new overhead-valve engines have overhead camshafts. On the other hand, several makers well known for their overhead-valve engines, as Delage and Armstrong-Siddeley, have adopted side valves for new light-six models. For ignition, the magneto is slowly losing ground to the coil, mainly due to the influence of the new six-cylinder engines.

Considerable trouble has been experienced with the distribution systems of new six-cylinder engines, and many makers are now using a dual carbureter with duplicated choke-tube and jet assemblies fed from a common float-chamber, each part serving three cylinders. A device undergoing experiment consists of a thermostatically controlled carbureter-inlet fitting having an open branch and a second branch leading from an exhaust stove. Each branch is fitted with a butterfly valve, as shown in Fig. 5. In this way the air supplied to the carbureter can be maintained at a constant temperature; 100 deg. fahr. has been found to give good all-round results on British gasoline.

Thermostatic control for cooling systems is popular. For medium-size engines many makers are using an impeller to assist water circulation. This is housed at the front of the cylinder-block and mounted at the rear end of a belt-driven fan-spindle. Air and oil-cleaners are receiving a great deal of attention.

Stiffer crankcase-cylinder castings, engine supports embodying flexibility, and timing gears at the rear end are well-marked trends. On the Wolseley straight-eight the drive to the overhead camshaft is placed at the center of a two-piece crankshaft. Duplex roller-chains are widely used for camshaft drives.

Transmission tendencies can be gathered from Table 3 and Fig. 6. The most popular layout consists of a single-plate clutch, unit-constructed four-speed transmission with central control, enclosed propeller-shaft, and spiral-bevel-gear final drive. Mechanical universal-joints are steadily displacing the fabric-ring type for unenclosed propeller-shafts.

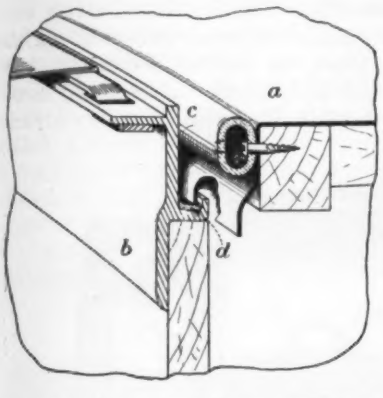


FIG. 12—FLOATING JOINT BETWEEN COWL AND DASH ON FLEXIBLY-MOUNTED BODY

This Allows Relative Movement of the Cowl, *a*, Built on the Body, and the Dash, *b*, Supported on the Chassis. The Joint Is Sealed by a Flattened Rubber Tube, *c*, below Which Is a Drip-Channel, *d*, To Catch Rain Water and Lead It Out to the Sides

In the chassis for which a unit construction of engine and transmission is not employed, a popular scheme is to build up the transmission, torque tube and rear axle to form a unit stiffened by a triangulated tie-rod arrangement. Leading examples are the Renault and Armstrong-Siddeley (See Fig. 7).

A few Continental makers, notably Voisin, are providing certain of their models with an auxiliary two-speed gear behind the transmission, so making two sets of forward-speed ratios available according to the nature of the district in which the car is running. In one chassis recently introduced, the gearshifting is effected by engine suction. The most striking transmission development in the offing is the free-wheel, described in the fourth section of this paper.

TABLE 3—CHASSIS FEATURES OF BRITISH AND CONTINENTAL CARS

Volumetric Capacity

	Per Cent
Under 1½ Liters (91.53 Cu. In.)	29½
From 1½ to 2 Liters (91.53 to 122.30 Cu. In.)	23½
From 2 to 3 Liters (122.30 to 183.06 Cu. In.)	25½
Over 3 Liters (183.06 Cu. In.)	21½

Number of Cylinders	Per Cent	*Forward Speeds*	Per Cent
Four	55	Four	72
Six	38½	Three	28
Eight	6½	*Gearshift Lever Location*	
Type of Valve		Central	58
Overhead Poppet	55	On Right	42
Side-by-Side Poppet	33	*Propeller-Shaft*	
Sleeve	12	Enclosed	56
Ignition		Unenclosed	44
Magneto	79	*Final Drive*	
Coil	16½	Spiral-Bevel	90
Dual	4½	Worm	10
Cooling		*Front Springs*	
Pump or Impeller	55½	Semi-Elliptic	96
Thermosiphon	43½	Quarter-Elliptic	4
Air	1	*Rear Springs*	
Clutch		Semi-Elliptic	67
Single-plate	76	Quarter-Elliptic	10½
Cone	12	Cantilever	18
Multiple-disc	12	Others	4½
Transmission Location		*Brakes*	
In Unit with Engine	76½	Four-Wheel, Plain	70
Separate	23½	Four-Wheel, Servo	25½
		Two-Wheel, Rear	4½

Note.—Percentages are based on an analysis of 255 individual European chassis on sale in Great Britain, including 135 British, 75 French, 18 Italian, 10 German, 8 Belgian, and 9 other European makes.

SPRING SUSPENSIONS AND STEERING

Except for a few makers having small outputs and advanced ideas, whose products are described later, suspension systems remain much as they were in all essentials. Semi-elliptic springs fore and aft, damped by four shock-absorbers, is the general rule. On most of the larger cars, however, rear springs of the cantilever type are employed, but, as shown in Fig. 8, they have been losing ground to the semi-elliptic type. Renault cars constitute an important but isolated example of the use of a transverse semi-elliptic rear spring. The axle anchorage on semi-elliptic front-springs usually is offset considerably, and on an increasing number of cars these springs are shackled at the front instead of at the rear end.

Cam-and-roller steering-gears have obtained a considerable following in England, but otherwise there have been few changes in steering. Certain chassis have interesting modifications of the orthodox layout, such as the 2-liter (122.02-cu. in.) Rover and the Daimler double-six, in each of which the steering-gear casing is mounted high above the frame level, close to the dash. The advantages of this position are that the steering column can be very fully raked, making the wheel pleasant to handle, and that the steering-gear does not obstruct access to the engine.

The drop-base wheel-rim introduced by Dunlop about four years ago has been widely adopted, as it has proved safe and yet permits of remarkably easy dismounting and mounting of the tire casing. Last year the Michelin Company introduced a different type in which the drop or well is eccentric, having full depth at the valve and tapering off in each direction around the rim until it vanishes opposite the valve. The valve is fitted with a rubber pad that fills the well of the rim when the tire is inflated.

Wire wheels have become increasingly popular with the introduction of bolt-on types such as the Rudge-Whitworth.

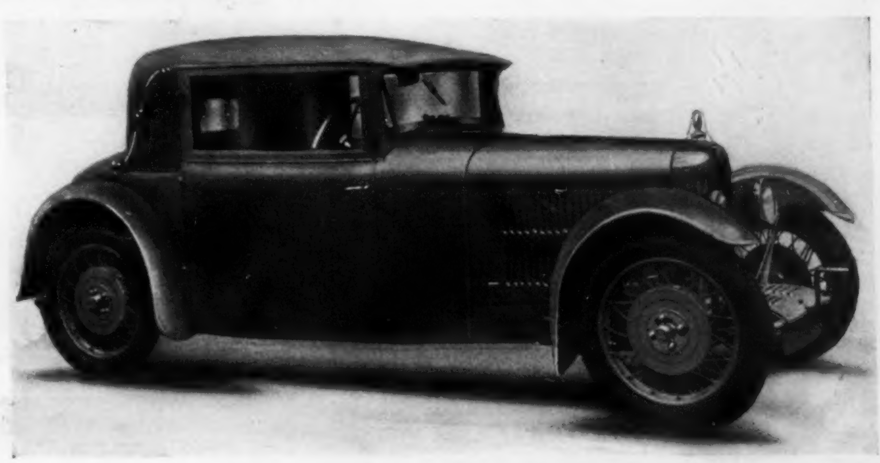


FIG. 13—CLOSE-TO-THE-ROAD TYPE OF BODY

Running-Boards as Well as Valances, or Running-Board Aprons, Are Being Discarded by Some Makers To Give a Closed Car the Desired Low-Hung Appearance. Fenders Are of the Bicycle-Mudguard Type and Are Attached to the Axle or Back Plate of the Brake Instead of to the Chassis Frame. Folding Steps Are Fitted beneath the Doors

3—DEVELOPMENTS IN BODY-WORK AND EQUIPMENT

An extraordinary diversity of body styles and types is noticeable in Europe at present. All-steel bodies are being turned out by a few large producers, such as Morris, Citroen, and Fiat, but composite bodies paneled in steel or aluminum and either finished in cellulose or covered with fabric are the most popular. The true Weymann flexible fabric-covered design is being made under license by numerous concerns, and a host of special designs emanate from the smaller firms. Such is the lack of uniformity in current practice that only a few leading examples can be mentioned herein.

The fashion for fabric bodies, a generic term used to include all bodies in which a covering of leather-cloth is employed instead of cellulosed panels, started in France two years ago and has passed its zenith there; in the opinion of many competent observers, the crest of the wave has been reached in England this year. The type originated with the ingenious flexible body-framework, covered with fabric, invented by C. T. Weymann. A valuable feature of the design, which has been widely copied, is that the body is merely a shell which protects the occupants but carries no weight.

Rigid Fabric-Covered Body-Work

When the demand for fabric body-work grew to important dimensions, many firms decided to produce an ordinary paneled composite-body that could either be cellulosed or covered with fabric according to requirements. By so doing they avoided alterations to plant and the payment of Weymann royalties and were able to obtain body contours less square-cut and severe than those of the truly flexible job. A good British example is the six-cylinder Crossley four-light saloon shown in Fig. 9. Incidentally, the four-light design, with wide doors, is very popular in Europe for fabric-covered bodies of all types.

Another line of development is represented by the three-point-mounted rigid fabric-covered body built by various well-known concerns. The leading British example is the Gordon-England, the construction of which is shown in Fig. 10. Here, as in the Weymann, the floor is separate from the body shell. This shell, however, instead of being flexible, is a rigid wooden struc-

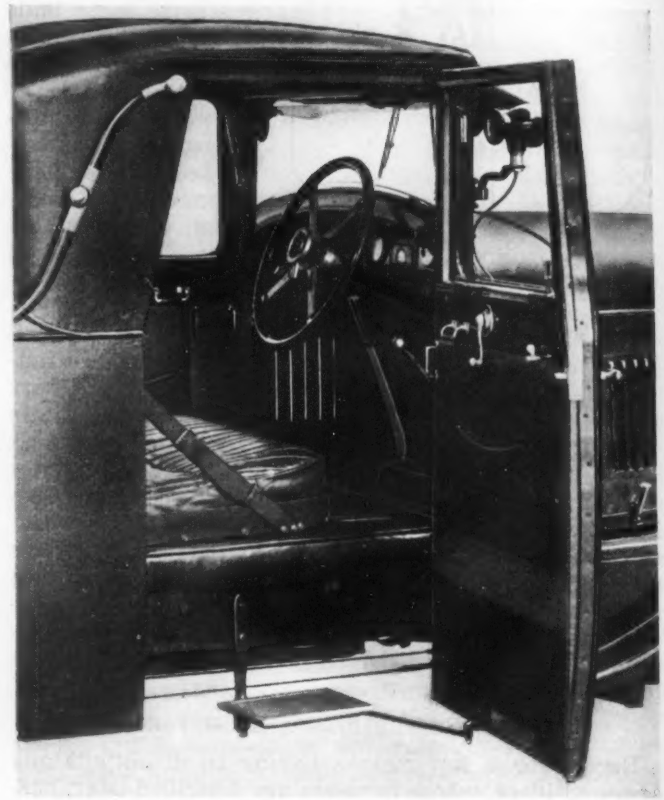


Fig. 14—Low Weymann-Type Coupé Body

The Over-All Height of This Body by Gurney Nutting Is Reduced by Using a Pneumatic Seat-Cushion of Small Depth. Note the Door and Body-Side Projection below the Chassis Frame, the Absence of a Running-Board, and the Concealed Step

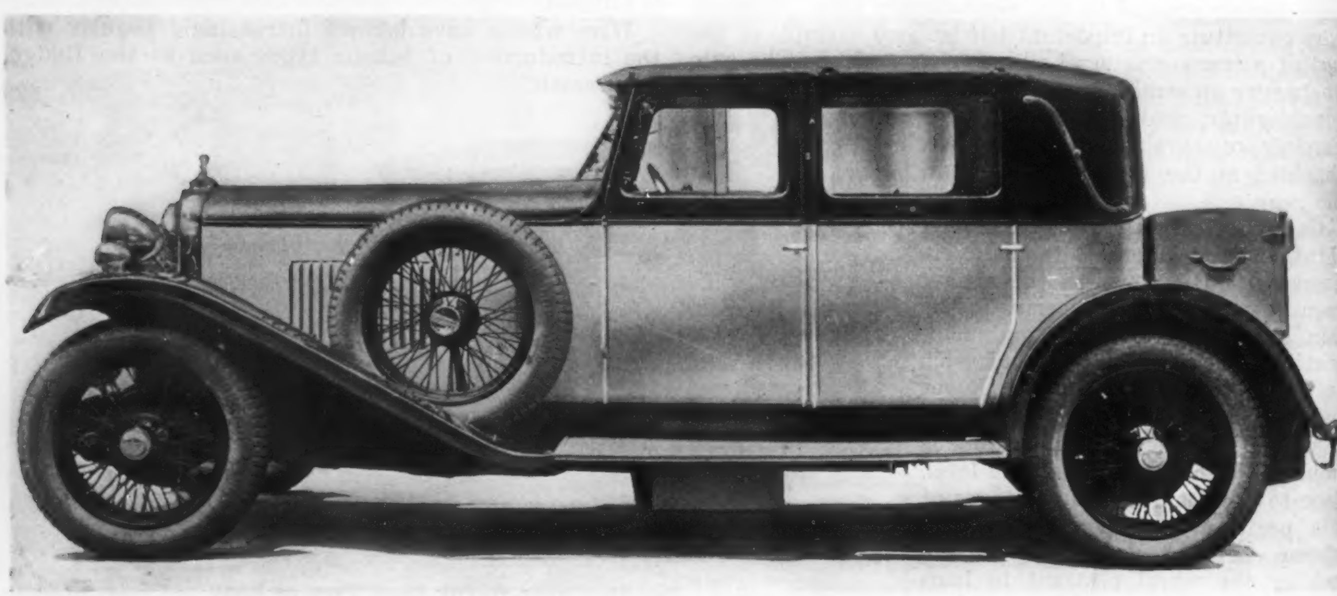


Fig. 15—A Notable Body-Development This Year, the Sunbeam Close-Coupled Four-Door Saloon

Of All Body Types the Four-Door Saloon Is Now by Far the Most Important in Europe for All Sizes of Chassis. The "Four-Light" and "Six-Light" Designs Are About Equally Popular. By Shortening the Body as Here Shown and Using Two Instead of Three Side-Windows, or Lights, the Luggage-Container Can Be Mounted on the Rear without Undue Overhang

ture with the framing stiffened by three-ply panels and the necessary strength against bending provided by box-section girders along the bottom edges. The shell is immune from the effects of chassis-frame whip, as it is secured at three points only: by brackets at either side of the cowl and by a central anchorage on a rear cross-member. One of the forward supports is shown in Fig. 11, which also illustrates how the bottom edge of the body extends downward outside the chassis frame to within an inch or so of the running-board, making a valance unnecessary.

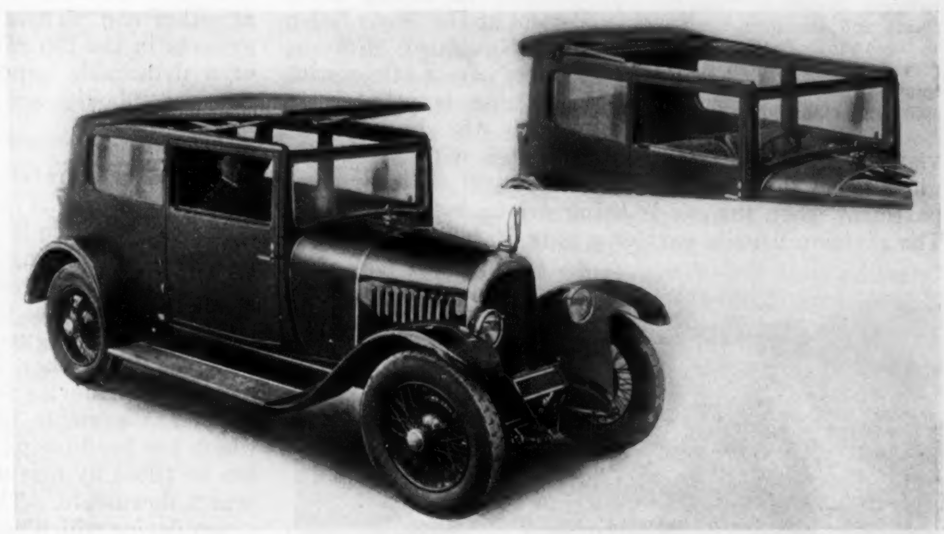
Flexible Body-Mountings

These and other designs have caused considerable attention to be directed to the safeguarding of body-work against wracking by chassis whip. For example, in large cars it is now common practice to build the body on a steel or cast-aluminum sub-frame, this being separated from the chassis frame at the four or six points of attachment by rubber buffers. The Daimler Company has been using this system of body insulation for some time.

When the body is flexibly mounted, allowance for relative movement must be made between the cowl and dash, the latter being bolted rigidly to the chassis and carrying the rear end of the hood, the brackets supporting the instrument board, the steering column, and so on. A popular form of cowl joint, illustrated in Fig. 12, embodies a flattened rubber tube and a drip channel located between the cowl and the dash.

Eliminating the Valance

The growing European practice of eliminating the valance by extending the body sides and doors downward outside the frame is being done not only for convenience but also because it assists in giving to a closed car that close-to-the-road appearance which is now so fashionable. As a further step the running-boards are being discarded by some makers, who mount small fixed or folding steps beneath the doors, with close-fitting fenders supported from some part attached to the axle, such as the back-plate of the brake, instead of from the chassis frame. A good Continental example is the coupé shown in Fig. 13. Another interesting example is the Gurney Nutting body, partly shown in Fig. 14, which is made under Weymann license. This shows also how over-all height can be reduced by using a pneumatic seat-cushion of small depth, which is another well-marked trend.



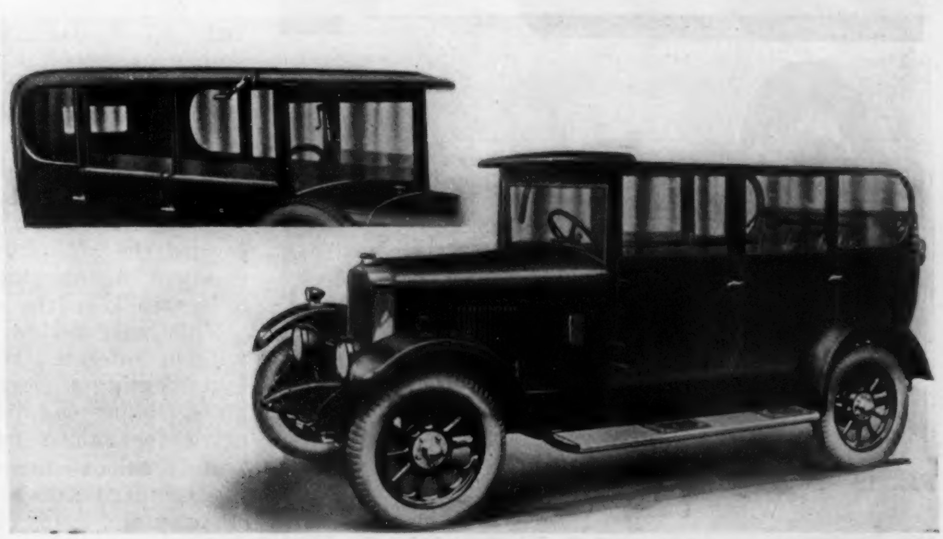


Fig. 16—Bodies Readily Convertible from Open to Closed Form

Convertible Bodies Have Now Definitely Met the Fancy of the Large Number of Persons Who Prefer To Ride in the Open in Suitable Weather. At the Left Is the Tickford Open-Air Saloon Having a Flexible Top Carried by Hinged Bows Operated by Means of a Detachable Crank, as Shown. At the Upper Right Is the Kopalapso Two-Door Body Having a Flexible Top That Can Be Folded Back Like a Phaeton Top. At the Lower Right Is the Alexander Demountable Top That Can Be Rolled Off at the Back by Means of a Transverse Rod Having Pinions at Either End. The Pinions Roll on Racks Recessed into the Top Rails of the Body Frame and Are Rotated by Means of the Detachable Handle Shown

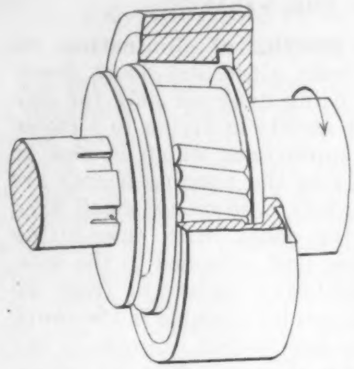


FIG. 17—NOVEL FREE-WHEEL CLUTCH

Much Work Is Being Done in Europe on Free-Wheel Transmissions or Drives in Which an Over-Running Clutch Is Placed between the Main Transmission-Shaft and the Propeller-Shaft or in the Final Drive. The Humfrey-Sandberg Clutch Above Has Skewed Rollers between Races Ground to a Concave Contour

Of all body types the four-door saloon is now by far the most important in Europe for all sizes of chassis, with four-light and six-light designs approximately equal in popularity. A notable development this year has been the close-coupled saloon, which is a four-light body shortened to enable a permanent luggage-container to be mounted at the back without undue overhang, a good example of which is seen in Fig. 15. Examples were noticed on almost every stand at the Paris Salon last November. For the larger cars a saloon with partition is popular, in which the built-in division behind the front seats is fitted with a framed-glass panel that can be raised to cut off the rear compartment when the car is being driven by a chauffeur. The division usually carries a pair of folding seats.

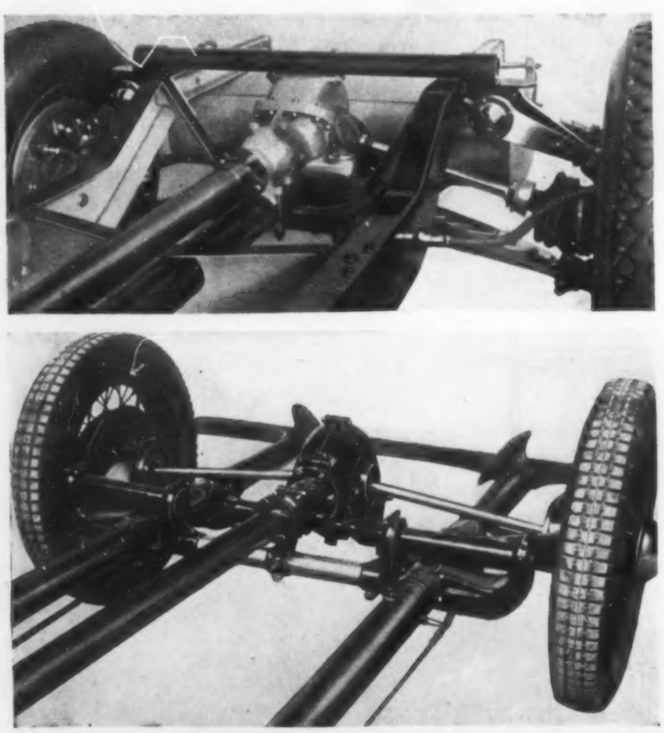


FIG. 18—TWO DESIGNS OF INDEPENDENTLY SPRUNG REAR-WHEEL CHASSIS-CONSTRUCTION

Above Is Shown the Sizaire System, Which Includes the Final Drive through Universal-Jointed Live Axles. The Wheels Support the Chassis by the Transverse Spring and a Pair of Pivoted Arms. Below Is Shown the Harris Leon Laisne System in Which Each Wheel Is Attached to a Transversely Pivoted Arm. A Vertical Stud on the Pivoted Arm Works Against Coiled Springs in the Tubular Side-Member of the Frame, Thereby Dispensing with Leaf Springs and Making Possible an Extremely Low Frame-Level

Another important body type this year is the "open-air" or "sunshine" saloon in which the rails and window frames form a permanent structure at either side, but a part or the whole of the top can be folded down. This type of body, suggested in a series of articles in *The Motor* a few years ago, has now definitely "caught on" in England owing to the number of persons who are adopting saloon bodies but dislike a permanent top.

The Pytchley Company pioneered the sliding-roof type of open-air saloon in which the forward portion of the roof is mounted on rails and can be slid back over the fixed rear portion. Another principle is represented in the Tickford body, in which a flexible folding top, carried by hinged bows, can be raised or lowered by turning a detachable handle, as illustrated in Fig. 16. Other makers are employing a smaller folding top, such as the Kopalapso, the rear quarter of the body being fixed. One of the most ingenious of these folding tops is the Alexander, in which the forward edge of the flexible roof is secured to a transverse rod carrying a pinion at either end. These pinions mesh with racks fitted to grooves in the top rails and can be traversed by means of a detachable handle. Both the Kopalapso and the Alexander bodies are shown also in Fig. 16.

EQUIPMENT

Only a brief reference to a few items of equipment seems necessary, as in very many respects European and American practice is similar. The permanent luggage-container, consisting of a metal or three-ply wooden shell containing three or more suitcases, is a practical fitting and improves the appearance of the rear of a car.

Equipment designed to minimize the headlight-dazzle nuisance is another important item. In England the most popular device for this purpose is the "dipper", an important example of which is the Barker system in which the head-lamps are carried on pivots so that they can be tilted by means of a lever and rods to throw the beams downward. This has latterly been improved by a cam device which causes the lamps to turn toward the side of the road as they are dipped, producing a dip-twist effect. Of more recent introduction, but already widely used, is the Lucas system, in which the head-lamps are fixed but carry pivoted reflectors. As the moving parts are very light, the designer has been able to incorporate a push-pull pneumatic control which is easy to operate. A dip-twist effect is secured by mounting the reflectors on pivoting axes that are inclined instead of horizontal. This throwing of a dipped beam toward the side when meeting another car gives an excellent non-dazzling driving light and enables the driver to keep the edge of the road always in view.

This brief review of equipment would be incomplete without reference to unsplinterable safety glass made by cementing a sheet of celluloid between two sheets of glass. Many car makers now list this as an optional extra for saloon models, and others are producing "safety saloon" models selling at a higher price than the standard saloon and fitted with safety glass and other special items of equipment. Many new manufacturing companies have recently been formed in England in anticipation of a great increase in the demand for glass of this kind.

4—CHASSIS CHANGES IN PROSPECT

This section deals briefly with chassis changes of importance that have already been put into practice by

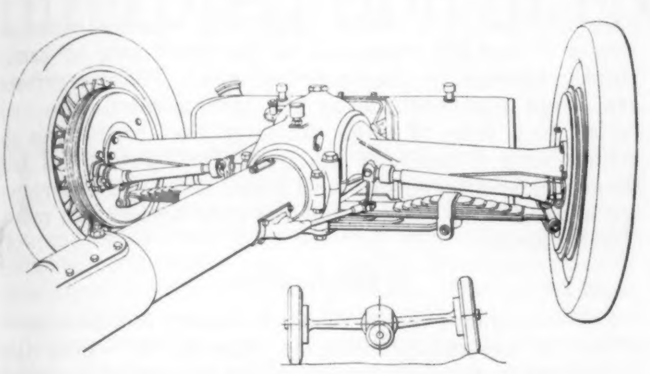


FIG. 19—AUSTRO-DAIMLER INDEPENDENTLY SPRUNG WHEEL CONSTRUCTION

This Frameless Chassis Has a Tubular Backbone That Terminates in a Spherical Differential-Housing and Articulated Joint in Which the Ends of the Live-Axle Housings Work. A Triple Transverse Spring Carries the Load, and the Wheels Can Move Independently, as Illustrated by the Insert Drawing

certain small concerns which make cars in limited quantities, are remarkably progressive in their ideas, and give considerable impetus to mechanical developments. Their ideas possess attributes of an importance sufficient to ensure that they will be carefully considered, and possibly eventually adopted, by the larger companies.

FREE-WHEEL TRANSMISSIONS

A great deal of work is being expended upon transmissions in which an over-running clutch of the free-wheel type is placed between the main transmission-shaft and the propeller-shaft or in the final drive. This system appeals chiefly on the score of easy gearshifting, as with it gears can be changed with remarkable facility when the ordinary clutch is thrown out, the driver having to contend only with the inertia of the freely spinning gear-shafts. Furthermore, a great deal of free coasting is made possible, which results in more pleasurable motoring and a saving in fuel amounting to about 25 per cent. On the other hand, the driver loses the braking effect of the engine, although he may be given an emergency control for locking the free-wheel when necessary.

The leading British free-wheel is the Humfrey-Sandberg, shown in Fig. 17, which consists of a set of cylindrical rollers fitted on the skew between races ground to a concave contour. This device gives free movement for one direction of torque, but a reversal of torque causes an immediate "pick-up" of the drive, accompanied by an axial "screw-in" movement of the parts. This pick-up can be prevented by inserting a stop to prevent the axial movement, a feature which is used in providing a locking device, as follows: Two such clutches, left-hand and right-hand, are mounted behind the transmission case, the former being normally kept out of action by a stop while the latter gives a free-wheel drive. Operation of a locking lever withdraws the stop, so allowing the left-hand clutch to operate to give a "solid" drive for reversing or emergencies.

The de Lavaud free-wheel device has only recently been introduced but has already attracted much attention in England. It consists of two roller-clutches mounted on the rear-axle half-shafts in place of the differential. This scheme gives, in addition to its free-

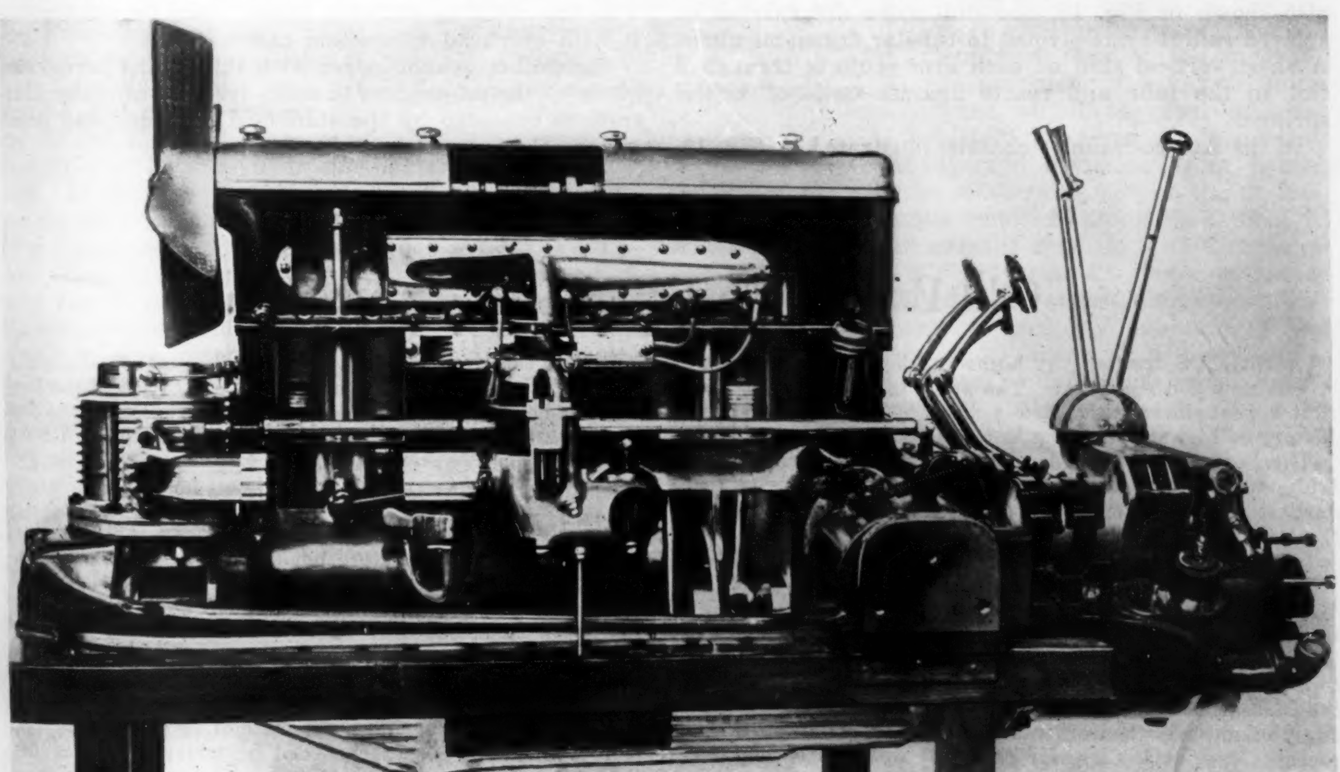


FIG. 20—SUPERCHARGED SIX-CYLINDER MERCEDES ENGINE PARTLY IN SECTION

A Roots-Type Blower at the Front End Is Brought into Action by a Clutch When the Accelerator Pedal Is Depressed beyond Its Normal Range. The Supercharger Is Intended for Use Only When Extra Power Is Needed. Road Tests of the Mercedes Car Fitted with This 381.13-Cu. In. Engine Showed It To Have Maximum Speeds of 100 M.P.H. with the Blower in Action and 80 M.P.H. without. On a Third-Gear Ratio of 4.6 to 1, the Car Could Be Accelerated from 10 to 60 M.P.H. in 15 Sec.

wheel properties, the advantage of a differential which prevents wheel-spin.

Front-wheel-drive cars for sale to the public are represented chiefly by Alvis in England and Tracta in France. In each case the chassis is of the sports type and is notable for low build and independent wheel-springing. The author can testify to the advantages of a front drive for cars of this class from personal experience in driving the Alvis; turns which would reduce the safe speed of a normal rear-drive car to about 30 m.p.h. can be taken at 40 to 45 m.p.h. without any feeling of insecurity. Another feature is the steering; no caster angle is needed, so the steering-gear can be made fairly direct or quick, yet light to operate. The driver has the sensation of controlling the direction in which the propulsive effort is being applied to the car instead of the usual sensation of steering the car against its natural inclination to run straight.

In addition to being used on the front-drive cars, independent springing of all four wheels is employed by Sizaire, Cottin-Desgouttes, Messier, and Harris Leon Laisne; while the same principle applied to two wheels only is used by Lancia, Steyr and Austro-Daimler. Remarkably easy riding, light unsprung-weight, absence of wheel-spin, a low frame-level and elimination of front-wheel shimmy are the principal advantages claimed.

In the Sizaire system, shown in Fig. 18, unenclosed cardan-shafts convey the drive from a differential housing mounted on the frame to wheels carried between the ends of a transverse semi-elliptic spring and pivoted arms. The Cottin system is similar, but transverse springs are employed both above and below the stub axles. In the very novel Harris Leon Laisne chassis, also shown in Fig. 18, the stub axles are carried by splayed radius-arms pivoted to tubular frame-members. A short vertical stud on each arm projects through a slot in the tube and reacts against enclosed helical springs.

In the Austro-Daimler chassis, illustrated in Fig. 19, are side members which carry the engine-transmission unit and are connected to the front axle by semi-elliptic springs in the orthodox way. These members are swept together behind the transmission case and bolted to a tube of large diameter that terminates in a final-drive housing to which two half-axle tubes are connected by a large spherical joint. Transverse springs are employed, as shown, and the rear wheels can move independently.

Supercharging

For some years the Mercedes Company has been marketing a supercharged-engine chassis in which the blower can be brought into operation at will by means of a clutch. When the accelerator pedal has traversed its normal range and the throttle is wide-open, increased foot-pressure against a stiffer spring operates the clutch and brings the blower into action. It is intended only for use on steep grades, for bursts of high speed, or for acceleration. Road tests of this car in England showed it to have maximum high-gear speeds of 80 m.p.h. without it and 100 m.p.h. with the blower in action. Using the supercharger, a speed of 60 m.p.h. could be reached from 10 m.p.h. in 15 sec. on a third-gear ratio of 4.6 to 1. The sectioned six-cylinder engine, which was exhibited at the Olympia show, is shown in Fig. 20. The capacity is 6246 cc. (381.13 cu. in).

At the 1927 Paris Salon many small cars of the 1½-liter (91.53-cu. in.) sports class were shown with Cozette superchargers fitted. In these, as in the British Lea-Francis, Riley, Vulcan, and Standard supercharged cars, the blower is in operation continuously. It is easier to make a four-cylinder side-valve-engine chassis into a sports model by fitting a blower than by redesigning it with overhead valves and camshaft.

The author acknowledges with thanks the permission given by the proprietors to make free use of many illustrations executed by the staff of *The Motor* and much information gained in their service.

Old Boston Post Road Modernized

AMERICA'S first lengthy highway, the Boston Post Road, is now 255 years old. The story of this ancient trail, first a post-riders' path, now a smooth rigid roadway, is a history of highway building in itself.

The Boston Post Road has evolved into one of America's truly modern thoroughfares. This route was one of the earliest roadways four traffic-lanes wide, and is considered the longest wide highway in the Country.

In the early winter of 1673, the first horseback post left New York City for the other principal city of the New World, Boston. This was the earliest attempt to link together these two cities, towns then, by land. The rider left New York City with messages from Governor Lovelace to Governor Winthrop of Connecticut and the Governor of the Massachusetts Bay Colony. At the end of the second day the message bearer was still in the confines of the present New York City, for the trail was poorly marked.

The first journey required two weeks. Later, when provisions were made for changing horses along the route, the time was reduced to one week, with 30 to 50 miles as the average daily distance. Frail bridges that trembled under the impact of horses' hoofs were erected to eliminate the countless fords necessitated by the meandering trail.

In 1713 the New York State Assembly established a right-of-way four rods wide between New York City and the Connecticut boundary. But it was not until 1772 that the first coach-journey was made, by Jonathan and Nicholas Brown. Riding on hard backless seats, the travel-worn tourist welcomed the end of the daily 40-mile jaunt lasting from sunup to sundown.

The need for paving was evidenced even in those days but the early attempts were not so successful. The "turnpiking" process consisted in placing a layer of rock covered with sand over the roadway. This gave an excellent roadway for a time, but soon rain washed away the sand and travel over the exposed rocks was more difficult than ever. Later, crushed stone and planking soothed the way of the coach-and-four.

Motor traffic, increasing at the rate of 10 per cent a year, made it mandatory that the road be widened. Even five years ago, from 10,000 to 16,000 vehicles used the road daily. For a time consideration was given to constructing a parallel route, but it was decided that it would be more economical to pave the Boston Post Road to a double width. The roadway, now concrete for the most part, is paved to a width of 36 or 40 ft.—*Motor Travel.*

Automotive Research

Interpretation of Exhaust-Gas Analysis[1]

> This contribution to Automotive Research is a comment by O. C. Bridgeman[2] on a previous article by Clarke C. Minter[3]. In his article Mr. Minter called attention to the presence of free oxygen in the exhaust gas from an engine even when the charge is known to contain fuel in excess. This condition he explained by assuming that the charge is not homogeneous, but burns as a mixture of mixtures. He then pictured the composition of the non-homogeneous change as a manifestation of the law of probabilities.

THE interpretation of exhaust-gas analysis in terms of the chemical processes which occur in the cylinder or cylinders of an internal-combustion engine is extremely difficult and still appears to be a moot question among those investigators who have experimented with this problem. One of the most serious difficulties arises from the fact that a number of the reactions involved are equilibrium processes with a high temperature coefficient, so that the composition of the exhaust gas at temperatures considerably below that existing in the cylinders cannot legitimately be employed to indicate directly the state of the combustion system in the engine. Furthermore, the mechanism of combustion under the conditions existing in the engine is so little understood that any accurate evaluation of the shift in these equilibrium reactions between the opening of the exhaust-valve and the analysis of the gas sample seems to be almost impossible in the light of the limited experimental evidence available at present.

The use of simplifying assumptions permits various interpretations of exhaust-gas analyses to be made which are not necessarily unique, being based on assumptions that appear plausible but are not founded directly on experiment, and do not always lead to conclusions that have been or can be verified by experiment. In other words, there is great need for an extensive study of the chemical reactions that occur in the cylinder, and, until such knowledge at least is available, attempts to draw quantitative conclusions about these reactions from the analysis of gas drawn from the exhaust manifold appears to be futile and to serve merely to obscure the lack of necessary experimental information.

Difficulties in Applying Theory of Errors

The application of the theory of errors to the interpretation of exhaust-gas analysis in terms of the distribution of air and fuel throughout the mixture at the instant of ignition, as suggested by C. C. Minter for an idealized system, is ingenious but barren. Whereas this method of attack may give the *type* of curves which represent the distribution of fuel in the mixture, it is necessary to *assume* a value for the modulus of precision, which is ordinarily evaluated from the experimentally observed deviations. It is difficult to understand how the modulus of precision can be evaluated in this case by experimental means, for it would involve not only sampling of the mixture from a sufficiently large and diverse number of portions of the total charge to make the application of the theory of errors valid, but the assumption that no diffusion occurred during this process of sampling, and still further that this was the state of the charge at the instant of ignition. The results so obtained would apply to the particular set of operating conditions at this instant. Treatment of such data, if obtainable, involves, according to the method of Minter, the assumption that the composition of the reaction products does not change during the time and the temperature drop occurring in the process of passing from the cylinder to the gas-analysis apparatus, which is inadmissible in practice. The reverse method of computing the degree of homogeneity of the charge from the exhaust-gas analysis, even assuming a "frozen equilibrium," is not possible, for there are more unknowns than there are equations for its solution.

The relation between the modulus of precision and the extent of evaporation of the liquid fuel in the charge appears to be entirely fictitious. The assumption that h, the modulus of precision, is equal to unity when all of the fuel is completely vaporized, is equivalent to stating that the average deviation from homogeneity of the gaseous mixture is 0.56 of an air-fuel ratio, which is a purely empirical assumption, since it is obvious that, with varying conditions of turbulence and time allowable for diffusion, all stages of homogeneity may be obtained, from almost complete separation of the fuel vapor to complete mixing. In the former case, the theory of errors is not applicable, whereas, in the latter case, no differences in concentration could be detected by analytical means. Since no information is available on the degree of homogeneity of the gaseous mixture at the instant of ignition, the arbitrary assumption of h being equal to unity may be very far from the truth. If the fuel is not completely vaporized but exists partly in the form of droplets throughout the mixture, the distribution of these droplets may be such that the same degree of homogeneity is indicated *by sampling* as would be indicated if the fuel were completely vaporized. In any case the value of h is a specific function of the design of the induction system and the combustion-chamber, and as such would normally have a different value for every engine and even for the same engine with every change in operating conditions.

If it is assumed that the modulus of precision, h, can be evaluated experimentally at the instant of ignition and, further, if it is assumed that the reactions speci-

[1] Published by permission of the Director of the Bureau of Standards, City of Washington.

[2] Research associate, Bureau of Standards, City of Washington.

[3] See THE JOURNAL, January, 1928, p. 19.

fied by Minter are the ones which take place during combustion, then the composition of the exhaust gas *in the cylinder immediately after an instantaneous combustion* probably can be evaluated by means of the theory of errors, for a charge in which all of the fuel is *completely vaporized* at the instant of ignition. Accepting these assumptions, the homogeneity of the gaseous mixture depends upon diffusion and turbulence, and, since the process of mixing is molecular, it seems reasonable that the variable concerned is the molal concentration of fuel or air in the mixture, or their equivalents. Since concentration is expressed in terms of the number of units of a particular substance in a specified number of units of the mixture, air-fuel ratio cannot be considered equivalent to concentration as a variable for this purpose.

However, if it is still further assumed that air-fuel ratio can be used as the variable in the error function, the integration of equation (13) of Minter's article to evaluate the volume of combustion products could be carried out between the limits of zero and infinity. The use of infinity as the upper limit is legitimate, since the integral derives practically all of its value over a very narrow range of deviations, and those of appreciable magnitude are very rare. If these limits are used, an exact integration can be performed to give the volume of carbon gases formed from that portion of the charge in which the fuel is in excess.

$$V_1 = 101\left[\frac{2h^2R}{2h^2R^2 - 1} + \frac{h}{\sqrt{\pi}(h^2R^2 - 1)}\right] \tag{1}$$

Similarly, for the case in which the air is in excess, there results

$$V_2 = 101\left[\frac{2h^2R}{2h^2R^2 - 1} - \frac{h}{\sqrt{\pi}(h^2R^2 - 1)}\right] \tag{2}$$

Hence, the sum of (1) and (2) would give the total volume of carbon gases formed under the conditions specified. This is

$$V = \frac{202}{R}\left[\frac{1}{1 - \dfrac{1}{2h^2R^2}}\right] \tag{3}$$

as compared with $202/R$ for the value computed by Minter for a homogeneous system.

The use of infinity as the upper limit of integration avoids the difficulty encountered by Minter in integrating from 0 to x, in which he was forced to make the unjustifiable approximation of taking the first term of a series, not always convergent, as equivalent to the entire function, and in this particular case is tantamount to a cancellation of a factor containing the variable in different functions in numerator and denominator, both behind the integral sign. After integration, he was further forced to make an extremely crude approximation to remove the variable x from the integrated expression, which is avoided in the present method by using definite limits.

Volume of Carbon Gases

If h is taken as unity for illustrative purposes, and if the relations employed by Minter for the hypothetical reactions occurring during combustion are used, a value may be obtained for the total volume of carbon gases from a mixture of air-fuel ratio 15 by means of equation (3). This volume is 13.50, as compared with the value 13.46 for the case of a homogeneous mixture and with the value 13.40 computed by Minter. It seems impossible that the volume of carbon gases can be less than the predicted value (13.46) under these conditions, and only in the limiting case of a perfectly homogeneous mixture would it be equal to the predicted value. Hence, the figure 13.40 and the "corrected" values used by him appear to be equally wrong. To prove this, consider a system with a mean air-fuel ratio of 15 to 1, and assume that the gas mixture is divided into two equal, perfectly homogeneous parts, with ratios $R - X$ and $R + X$ respectively. The volume of carbon gases produced from the total mixture would be

$$V = 101\left[\frac{1}{R - X} + \frac{1}{R + X}\right] = \frac{202}{R}\left[\frac{1}{1 - \dfrac{X^2}{R^2}}\right] \tag{4}$$

For all values of X except zero, V is greater than $202/R$. A similar statement holds true for the other products of combustion, assuming the ideal relations of Minter.

As a matter of fact, equation (4) contains all of the information that (3) does, and can be obtained very simply by straight addition rather than by integration of a relation based on further assumptions. In both equations it is necessary to choose empirically a particular value, in the one case for h and in the other for X; and it is as simple to pick offhand a value for the mean deviation without any assumption as to pick one for the probable deviation assuming that probability applies to the system. However, if it is desired to draw probability curves, the theory of errors predicts that the mean error X is equal to the reciprocal of $h\sqrt{2}$, so that direct substitution for X in equation (4) gives relation (3). The only assumption involved in this substitution is that the theory of errors is applicable to the system.

Exhaust-Gas-Analysis Calculations

E. H. LOCKWOOD[1], in a previous article[2], developed six algebraic formulas for calculating, from exhaust-gas data, information relating to the air and fuel constituents of combustion. He has recently extended his study along these lines, and has worked out formulas and diagrams on exhaust-gas analysis and resulting air-fuel ratios. In presenting this material, Professor Lockwood asks for criticisms of or suggestions concerning his work in its present form, and makes the following comments concerning it:

> It is, I think, rather surprising that the air-fuel ratio can be computed from only two of the gas-analysis items, say CO_2 and O_2, and yet include correctly the remaining items CO, H_2 and CH_4.
>
> We have been checking these formulas by exhaust

[1] M.S.A.E.—Professor of mechanical engineering, Yale University, New Haven, Conn.

[2] See The Journal, November, 1927, p. 571.

analysis from the Chrysler 80, and have obtained fully satisfactory agreement in comparing air-fuel ratios by metering the fuel and air and by calculation from gas analysis.

An interesting feature of the diagram is the check afforded on correctness of analysis by the common intersection of three gas-component lines in a single point, or in three closely adjoining points, referred to by *a*, *b* and *c* in Fig. 1. This check has been satisfactorily met by our best analyses, although in some instances divergent intersections have been found.

Wide separation of the points indicates inconsistency and consequent divergence in the values of the air-fuel ratio. Hence the diagram affords a simple means of checking the consistency of the gas analysis.

A definite point on the diagram will be associated with each analysis, and as the mixture strength changes the points will travel across the diagram in a narrow band. In general rich mixtures will lie along the axis where oxygen approaches zero at bottom of diagram, while lean mixtures will lie along the zero monoxide axis. Any marked deviation from the analysis band may be considered an indication of mixture of air with the exhaust sample, in the transfer of the exhaust from the manifold to the Orsat apparatus.

The formulas and diagrams developed by Professor Lockwood follow.

Air-Fuel Ratio of Internal-Combustion Engines Computed from Exhaust-Gas Analysis

Air-fuel ratios deduced[3] in terms of gas-analysis items, CO_2, O_2, CO, H_2, CH_4, N_2

Actual air-fuel ratio =

$$\frac{18.15N_2}{0.522N_2 + 4CO_2 + 5CO + H_2 + 8CH_4 - 2O_2} \quad (1)$$

Ideal air-fuel ratio for perfect combustion =

$$\frac{18.15N_2 + 34.8(CO + H_2 + 4CH_4 - 2O_2)}{0.522N_2 + \text{etc.}} \quad (2)$$

To simplify, substitute $N_2 = 100 - CO_2 - O_2 - CO - H_2 - CH_4$, and actual air-fuel ratio = R, ideal air-fuel ratio = 15.15, approximate relations by A. W. Judge[4]. $H_2 = 0.38CO$, $CH_4 = 0.13CO$, and obtain, after reduction,

$$R = \frac{79.3 + 0.430CO_2 - 0.568CO}{0.391CO_2 + 0.440CO} \quad (3)$$

$$R = \frac{66.8 + 1.29CO_2 + 0.604O_2}{9.68 - 0.278CO_2 - 0.468O_2} \quad (4)$$

The analysis percentages CO_2, CO, or CO_2, O_2, will yield the same value of *R* if the analysis is consistent with theory. Hence either formula (3) or (4) may be used.

The air-fuel ratio can be found without calculation by plotting the values of the four variables in (3) and (4) in a diagram shown in Fig. 1. In using the diagram, sketch in a line for each of the analysis items, as $CO_2 = 11.6$, $O_2 = 0.6$, $CO = 3.5$, parallel to the respective axes, which should intersect in a point for perfect agreement with theory. Ordinarily, perfect agreement will not be obtained, and three intersections will be obtained, as shown by *a*, *b*, *c*, on the diagram. The air-fuel ratio can be read from a line through the middle of *a b c*.

The air-fuel ratio diagram may have two incidental uses of considerable value, to detect analyses that have been incorrectly made, and to detect the mixture of air

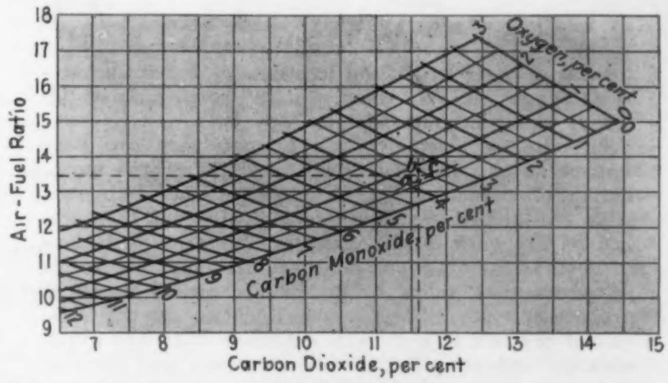


FIG. 1—DIAGRAM OF EXHAUST-GAS ANALYSIS AND AIR-FUEL RATIO FOR INTERNAL-COMBUSTION ENGINES USING PETROLEUM

The Air-Fuel Ratio Can Be Found Without Calculation by Plotting the Values of the Four Variables in This Diagram. In the Example Here Illustrated, $CO_2=11.6$, $O_2=0.6$, and $CO=3.5$. These Lines Sketched on the Diagram Give Intersections *a*, *b* and *c*. If These Points Coincide, Analysis Agrees with Theory. A Line Drawn from the Center of *abc* Gives the Air-Fuel Ratio as 13.4

with the exhaust gas sample during sampling or analysis.

Validity of Relations Questioned

O. C. Bridgeman, to whom Professor Lockwood's formulas were submitted, makes the following comments[5]:

> The computation of the average air-fuel ratio supplied to the cylinders of an internal-combustion engine from the complete analysis of a representative sample of the exhaust gas would seem to be a precise problem in stoichiometry, granting the usual assumptions. A certain average amount of carbon, hydrogen, oxygen and inert gases constitute the supplied mixture and if no "carbon" is left behind in the cylinders on combustion of this mixture and if none of the lubricating oil is burned, then it follows from the law of conservation of mass that the same amounts of these substances will be expelled from the cylinders into the exhaust manifold. Under these conditions, an adequate method of analysis of either the dry or wet exhaust gas is all that is required. The accuracy of the computed air-fuel ratio will depend entirely upon the removal of a representative sample and the accuracy of the method used for analysis.
>
> In order to simplify the analysis of the exhaust gas, certain assumptions are frequently made. One of the more common of these assumptions is that the residual gas after removal of CO_2, O_2 and CO can be considered for purposes of calculation as consisting of H_2, CH_4 and N_2, which may be legitimate in certain cases, but if accuracy is desired, its acceptance might introduce considerable error in the general case. The two additional simplifying assumptions introduced by Professor Lockwood, namely that $H_2 = 0.38 CO$ and $CH_4 = 0.13 CO$, appear to be very questionable, a priori, since they imply knowledge of the mechanism of combustion considerably in advance of that definitely established. No entirely satisfactory theory of the mechanism of oxidation of pure hydrocarbons is known at present and any gasoline is such a complex mixture that, even if the mechanism were known for each type of hydrocarbon, the percentages of the various types present in the particular sample would constitute the minimum knowledge necessary for the deduction on theoretical grounds

[3] See THE JOURNAL, November, 1927, p. 571.

[4] See Testing of High-Speed Internal-Combustion Engines, p. 103.

[5] Published by permission of the Director of the Bureau of Standards, City of Washington.

of relations similar to those given above. Unfortunately Professor Lockwood presents no experimental data to prove the legitimacy of the assumptions suggested. If extensive data showing the validity of the relations between CO, H_2 and CH_4 have been obtained even for one engine, they are very important and should throw some light on the mechanism of oxidation. Computations from published data on exhaust-gas analyses indicate that these relations are very crude averages and that deviations of several hundred per cent are common. It seems apparent that there exists no theoretical basis at present for permitting a simplification of the analytical procedure, and until extensive data are available on both supplied air-fuel mixtures and exhaust gas analyses, which for individual cases rather than averages give good agreement between the observed and calculated values, then any relations such as are suggested by Professor Lockwood must be regarded as very questionable.

While agreement between the values of R computed from equations (3) and (4) might constitute some evidence in favor of the assumptions involved, no data are presented to show how closely these agree, nor how well either of them reproduce the actual values of the mixture ratio supplied to the engine. In this connection, it is curious that modifications of Price's empirical relations are used in the deduction of equations (3) and (4), when the author's relations based on theory would introduce no additional mathematical difficulties, although they would give different final equations.

Carbon-Monoxide Research

THAT active interest is being maintained in the practical as well as the theoretical aspects of exhaust-gas study is shown by a number of committee activities as well as other evidences.

One such body is the recently formed Joint Committee on Atmospheric Pollution by Automobile Exhaust-Gases. It consists of delegates from the American Automobile Association, American Chemical Society, American Medical Association, American Petroleum Institute, American Public Health Association, Motor Truck Association of America, National Association of Taxicab Owners, National Safety Council, United States Bureau of Mines, United States Public Health Service, and the Society of Automotive Engineers.

The purpose of the committee is, in general, to furnish the public with authentic information concerning the subject of automobile exhaust-gases and the danger or lack of danger resulting from the pollution of the atmosphere with such gases. It will encourage research and investigation toward the reduction of the amount of carbon monoxide formed in automobile operation and attempt to eliminate this entirely if possible.

From information at hand regarding the amount of carbon monoxide to which the public is exposed and the probable effects of such amounts, the Committee is led to believe that no alarming condition exists in the thoroughfares. However, in confined places, such as some cab stands, enclosed driveways and commercial garages, the carbon-monoxide health-hazard is more pronounced. The educational efforts of the Committee will be directed particularly to correcting conditions that are wrong in such places.

Another organized effort to ascertain the extent of the carbon-monoxide health-hazard and methods for its elimination is being fostered by the Department of Health of the City of New York. A preliminary conference was held on June 26, to which were invited persons interested in the manufacture of automobiles and at which this Society was represented.

The ventilating system of the Holland Tunnel, the primary data for which were prepared from many extensive and carefully conducted experiments, is being carefully watched to see if it is adequate under actual traffic conditions. A recent report of its effectiveness on the first and second days of the operation of the tunnel, made by S. H. Katz and H. W. Frevert, Pittsburgh Experiment Station, Bureau of Mines[1], contains much carefully gathered and interesting information both on the tunnel usage and the efficiency of the ventilating system.

One section of this report deals with the amount of carbon monoxide evolved per car. It is particularly worthy of study since it gives opportunity for making comparisons between different conditions of operation and between experimental determinations and actual results. The amount of carbon monoxide produced per car-mile, for instance, was found to vary with the grade of the tunnel roadway. On a grade of 3 per cent the average volume of carbon monoxide evolved per car-mile was 5.5 cu. ft., when on a —4.03 per cent grade the average volume of carbon monoxide evolved per car-mile was 2.3 cu. ft. Another fact commented on is that slightly more carbon monoxide appears generally in the South than in the North Tunnel. The reason is presumed to be that a less steady outlet of heavy traffic takes place from the South Tunnel due to interruptions in crossing traffic arteries in New York City.

On the second day of operation, the carbon monoxide evolved was found to be in excess of what would have been expected on the basis of experimental data. The maximum difference amounted to 29 per cent. Part of the discrepancy is attributed to the grade of 3.48 per cent whereas a 3.0 per cent grade was used in the tests. The greater and less economical speed of 30 m.p.h. maintained in the tunnel as against the 15 m.p.h. speed of the tests is thought to be a second contributing factor.

Further evidence that the subject of carbon-monoxide research is being watched with attention is the interest shown in the recently published article, Automotive Phases of Carbon-Monoxide Research Summarized[2]. This incorporated a report made by the Research Department at the direction of the Research Committee and briefly summarized the main points of the general carbon-monoxide research, but dealt in somewhat greater detail with subjects of special interest to the automotive industry.

Requests for reprints of this article have represented interest abroad as well as in this Country, and have come from Government and State bureaus, universities, associations, and commercial organizations. A few reprints are still available for those desiring copies.

[1]See *Industrial and Engineering Chemistry*, June, 1928, p. 564.
[2]See THE JOURNAL, May, 1928, p. 570.

Operation and Maintenance

Operating Safety Measures

Committee Studying Selection and Training of Fleet Drivers

ONE of the principal topics scheduled this year for study by the Society's Operation and Maintenance Committee is the selecting and training of drivers for motor-vehicle fleets. Operating safety measures is a collateral subject. A great deal of study has been given this matter by the operators on the Western Coast. Ethelbert Favary, a member of the Operation and Maintenance Committee, will report on these activities at the National Transportation Meeting of the Society to be held in Newark, N. J., Oct. 17 to 19. He has prepared the following outline, which is printed in this issue of THE JOURNAL to apprise the motor-vehicle fleet-operating members of the Society of the points his report will cover. It is particularly requested that interested members send directly to Mr. Favary, Moreland Motor Truck Co., Box 317, Los Angeles, or through the Society's office, comments or suggestions they wish to make, in time to be helpful in the preparation of the report.

SYNOPSIS OF REPORT

Different methods are employed by different corporations in the selecting and training of drivers, and to assure safety of operation and freedom from accidents. Broadly speaking, the following fundamentals are recommended for consideration:

SELECTION

(1) Past experience.
To judge qualifications.

(2) Character.
To judge reliability and sense of justice regarding rights of others.

(3) Physical condition.
Applicants not in good health rejected.

(4) Age.
Corporations have age limits for drivers.

(5) If married.
Married men are preferred by some companies.

(6) Intelligence test.
Ability to form good judgment quickly. Required by corporations where drivers fill out forms and make reports.

(7) Traffic laws.
Applicant must be familiar with local and State traffic laws.

(8) Personal appearance.
Especially required by taxicab and motorcoach companies or where drivers contact with clients.

(9) Actual driving-test.
Ability to handle equipment.

(10) Coordination between mind and body.
To test response of muscular system to meet emergencies.

> **Transportation-Meeting Details**
>
> **All members interested in operation and maintenance should inform themselves regarding the plans for the Transportation Meeting which is to be held in Newark, N. J., Oct. 17 to 19. Details are given on p. 227 of this issue of THE JOURNAL.**

TRAINING

(Companies, with few exceptions, do not train novices.)

(1) Class instruction to familiarize drivers with equipment used.

(2) Care of equipment.
Training drivers to exercise care in handling equipment.

(3) Actual driving, accompanied by supervisor.

(4) Filling out forms and making reports.

(5) Securing witnesses in case of accidents.

(6) Safe and careful operation.
This is stressed at time driver enters company's service and periodically thereafter.

(7) Vigilance.
Constant vigilance continually impressed on drivers.

OPERATING SAFETY-MEASURES

(1) Each accident, however small, strictly investigated.

(2) Penalties assessed where accidents are caused by driver.

(3) Posting records of accidents.
Includes accidents to other persons and other property, as well as to company's property. Draws attention daily to accidents.

(4) Stimulating rivalry among drivers for freedom from accidents.

(5) The merit system.
Wage increase, taking cognizance of accident record of driver.

(6) Periodic talks by higher officials on safety measures.

(7) Observance of road rules.
Drivers must pay their own fines for speeding.

(8) Supervision.
Checking speed and recklessness of drivers.

PAYMENT

Paid by hour from 50 cents to $1, or by week or month. Guaranteed minimum from $100 to $150 per month. Long-distance stage companies pay highest wages.

Proposed Standard Terminology of Marketing Functions

SINCE all are interested in marketing, as it pertains either to service parts or to service, standardization of the common terms used in this business of ownership transfer is desirable. The terms to which reference is made are marketing, distribution, merchandising, warehousing, transportation, selling, and advertising. As indicated by the accompanying chart showing a proposed standard terminology of marketing functions,

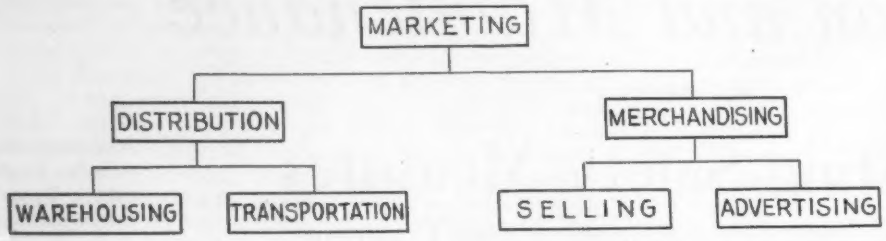
Marketing covers all the tangible and intangible methods and processes used by the manufacturer to effect change of ownership between the manufacturer and the consumer.

Distribution is designated as the machinery, or tangible methods and processes, by which the manufacturer conveys his goods to the consumer. The functions of this machinery are the divers services of supply, or, in other words, the attendant time and place utilities.

Warehousing includes the assembling and storage of goods.

Transportation represents the physical movement of goods from place to place, and from one functionary to another, regardless of means.

Merchandising is a one-word description of all the intangible methods and



instrumentalities used to move goods from the manufacturer to the consumer; it includes both the selling and the advertising processes in addition to all other efforts needed to move the goods.

Selling is constituted of those efforts which take the merchandise to the consumer.

Advertising is the effort which brings the consumer to the merchandise.

This business of ownership change, at least in the service-parts industry, has become more than just a business of offering manufactured goods for sale. The more we understand the meaning of the words we use, the less confusing becomes the issue, and the more we begin to think along lines which will be productive of the desired results in our field of endeavor. Clarifying the terminology we use tends to make us think along more definite lines, of definite functions and of their relation to one another. As a result, eventually we should be able to design a Marketing Plan with the same certitude that engineers have in designing an automobile or any other complete mechanical device.—A. R. Sandt, sales section, General Motors Corp., Detroit.

Mechanics Personnel

Subcommittee Studies Selecting and Training, Payment Systems and Time-Study

THE recent work of Subcommittee No. 3 of the Operation and Maintenance Committee, of which T. L. Preble is chairman, has been largely the collecting of data for the purpose of determining whether a standard course of training for mechanics can be applied to all types of men and also meet the requirements of both passenger-car shops and fleet owners. It has included consideration of the status of the Subcommittee in relation to other bodies carrying on similar investigations, the points that should influence or govern the selection of men to be trained, the most suitable type of training course, the securing of cooperation from the industry in carrying out suggestions that the Subcommittee may make, the most suitable method of wage payment, application of time-study, and investigation of the flat-rate system.

At the Subcommittee meeting held Aug. 7 in New York City, the types of school were discussed, the consensus of opinion being that they should be classified into four general groups; commercial, semi-endowed, endowed, and company-endowed schools. Commercial schools were defined as giving only what the student will buy; the others as giving only what the student should have. The object of the Subcommittee is to try to devise a training course that will be acceptable to all of the four classifications of school previously mentioned.

It was agreed that subcommittees should be appointed which would obtain data on the several sections of the work of the Subcommittee itself. These appointments were made, and the work the subcommittees are to do was assigned.

Regarding the selecting of men, the points influencing this include character, personality, adaptability, mechanical ability, past experience, previous education and ambition. Impressions made by the applicant during his preliminary interview are considered also, as well as whatever certificates of efficiency he may have.

Questions relating to the proper type of training course were debated. Among the subjects discussed were cooperative training as between the school and outside shops, details of proposed courses, the proper percentage of laboratory hours to working hours, the number of hours in the course, and what the tuition fee should be.

With the thought in mind that the present system of training mechanics has not met with any great amount of success, the Subcommittee is trying to develop some course of training which will result in a better type of mechanic and one who is better fitted for work under the flat-rate system. To this end, various flat-rate systems have been investigated and their good points brought out. An attempt has been made also to apply time-study to mechanical operations.

Suggestions and data from members interested in the subjects now being studied by the Subcommittee are desired. These should be sent to Mr. Preble, in care of the Standards Department of the Society, 29 West 39th Street, New York City.

Large-Scale Motor-Truck Moving Service

FORMATION of a Nation-wide motor-truck moving-service by cooperative enterprise of 153 of the leading moving and storage firms of the East and Middle West was the object of a recent conference. The service to be rendered by this organization, according to its officials, is designed to facilitate delivery and eliminate crating and packing expenses in moving household goods. The association plans to operate in 63 cities of the 17 States east of Nebraska and north of Kentucky, with Southern and Western lines to be added later. For use in this service, a truck body has been designed that provides sleeping quarters for a second driver so that long trips can be made continuous through day and night.

Motor-Vehicle Inspection

WHY not read the Symposium on Recent Motor-Vehicle-Inspection Procedure, which begins on p. 272 of this issue? Several phases of detailed inspection for maintenance and repair purposes are presented.

Production Engineering

Progressive Body Assembly

Layout Changes Made When Removing Truck-Body Plant to Larger Building

THE present body-plant of the Corbitt Truck Co. is contained in a building approximately 75 x 200 ft., one end of which is partitioned off as a blacksmith shop. A shed for iron storage is at the blacksmith-shop end of the building and a shed for lumber storage at the opposite end, as shown in Fig. 1. Production is being moved to another existing building of the same length but 100 ft. in width, in which the work can be arranged to better advantage.

In the present shop, a car on a track through the lumber-storage shed brings the stock to the cut-off saw just outside the door of the main building. The stock is then transferred successively to the planer, jointer, self-feed rip-saw, sticker or band-saw and mortiser and tenoner and shaper as required.

As the finished stock comes from the last cut, it is either distributed to the cab line or continued straight on to the body line, being stacked according to sequence of requirements at either point. Between these two points is a stockroom for sheet-metal, fastenings and accessories. Irons made in the blacksmith shop are distributed to points along both the cab line and the body line; as are also bolts, screws, nails and other supplies.

Near the beginning of the cab line are four forms over which are built the cab sub-assemblies, consisting of a base or floor, back, roof and front. Inside the form for the cab roof is a sub-form for assembling the rear door-post with its corner iron and seat side.

On lots of 25 of one size, a mechanic and a helper work on each form. All holes are bored and countersunk in the parts before stacking, so the assemblers are required only to pick up the parts as needed, drop them in place on the forms, tighten the clamps, fasten the parts together with screws or bolts, put on angle or corner irons, and apply the under-roofing or lining to the roof section.

Sub-Assemblies Made

As the sub-assemblies are taken from the forms they are passed to other assemblers, to make the final assembly on a set of oak rails set at a convenient height above the floor. These rails extend for a distance of 50 ft., level and parallel. Together with the use of forms, they assure that the finished cab shall be square.

While the cab frame is taking its form, sheet-metal men are cutting the metal so that when the cab reaches them they are ready to start applying the metal to the back, sides and cowl. They also apply the molding, which has been drilled and countersunk in the blacksmith shop. After this, the cab is pushed back to the door builders.

Doors for cabs, bodies and jobs of every kind are built by these door builders. Two men fit the doors that have been assembled, glued and fastened, and apply the metal after fitting. Then the cross-bars and glass felt are fitted and the glass is put in place. During this time a sub-assembly has been made, consisting of the door back, the lock with a remote control, and the window regulator. These are brought to the door and put in place; and the molding, one-piece piano-hinge and door handle are fitted. In finishing the door job, two men hang the door and fit strikers and anti-rattlers while one man fits the sliding glass in the felt at the back of the cab. The cabs are then trucked to the truck shop for trimming and painting.

In the new plant, shown in Fig. 2, the arrangements will be such that the cabs will pass a series of benches on which all parts are kept, instead of in a stockroom. This will save many steps and much time. Forgings, parts and material also will be stored at convenient points for instant use.

Another improvement will be that the cabs will pass to the trimming room and paint shop without leaving the rails until the paint is dry, when they will be mounted just outside the paint shop by means of a hoist.

Improved Methods

The present body line consists of two sets of rails, one on each side of the building. The finished parts are stacked between and near these lines so they can be picked up by two groups of men, who work progressively. After they have built the sills and floor, they slide these two units ahead to a point where four men begin to erect sides—which already have been assembled with stakes, top rail, metal and molding—while two other men place the roof bows or carlines and two more men set in the partitions. After this group pushes the body ahead, two men apply slats to the roof and another man inspects and applies the finishing touches, at the same time putting a sliding window in the partition, if this is required.

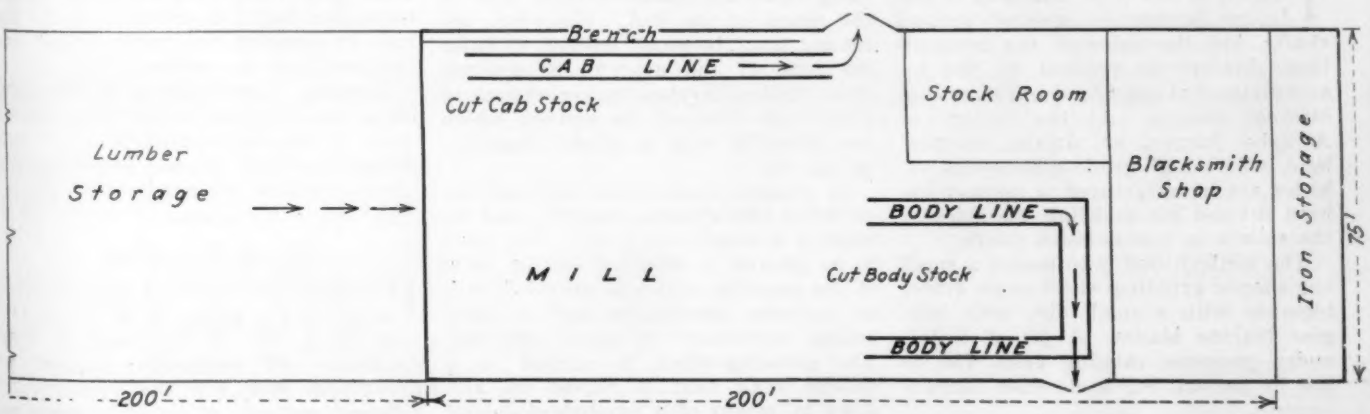


FIG. 1—THE PRESENT BODY PLANT OF CORBITT TRUCK CO.
This Building Is 75 x 200 Ft., with Storage Sheds Added at the Ends, for Iron and Lumber

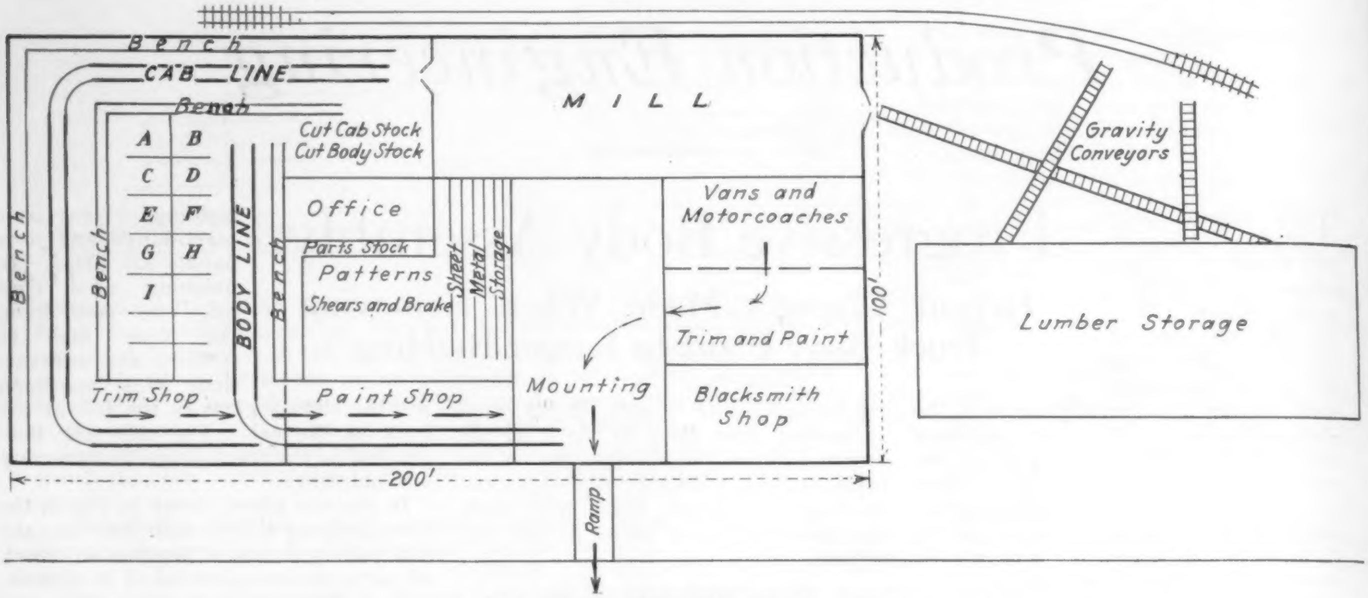


FIG. 2—THE NEW CORBITT BODY PLANT

This Existing Building, 100 x 200 Ft., Is Being Adapted To Include Assembly Methods In Which the Progressive Method Is More Completely Used. Divisions Indicated by Letters at the Left End of the Drawing Are Used As Follows: *A*, Cab Parts; *B*, Body Parts; *C*, Door Metal; *D*, Door Assembly; *E*, Hinges and Regulators; *F*, Glass and Felt; *G*, Screws; *H*, Bolts; *I*, Locks and Controls

Following this, two door-hangers bring the four doors and hang first the vestibule set and then the rear set, which is fitted with the customary turn-lock. Then the body either is mounted on a chassis that has been sent from the truck shop, or a truck calls for it.

A more progressive body-line will be used in the new shop, the men staying at one station and the bodies passing them as do the cabs. All metal will be cut and formed in the metal room in the new shop, then distributed along the assembly lines for both cabs and bodies to the points where it is to be used. There will be stockrooms to receive shipments, but there will be constant distribution of the stock to keep the two assembly-lines supplied and obviate the necessity for men to lose time in getting material.

The distribution can be handled by a boy, entries being made on a perpetual inventory as goods are received and distributed. Bodies and cabs will run through the same trimming and paint shops and be mounted by means of the same hoist. Van and motorcoach bodies will be built, trimmed, and painted in separate departments of the new shop, as shown in Fig. 2.—William Richards, Corbitt Truck Co., Henderson, N. C.

Grinding of Internal Splines

Novel Grinding-Wheel at the Saurer Works Driven by a Minute Turbine

THERE is now little difficulty in producing accurately ground splined shafts, but the value of the accuracy thus obtained is reduced by the inaccuracies that are found in the mating internal splines. At the factory of Adolphe Saurer, at Arbon, Switzerland, where high-grade commercial vehicles are manufactured, a method has been devised for grinding the sides of the splines in transmission gears.

The method used is to mount a small cup-shaped grinding-wheel on an arbor, together with a small disc with integral turbine blades. A jet of water, under pressure ranging from 140 to 350 lb. per sq. in., is directed tangentially upon the blades from a pipe in the shank of the tool. The whole assembly must be small enough to enter the bore of the gear to be ground. This turbine develops power enough to grind both sides of the splines, which are broached with a slight clearance at the top.

In general appearance, the machine on which this grinding-head is used resembles a small boring-mill. The gear to be ground is mounted on the table of the machine, which is provided with an indexing mechanism and a slight lateral movement to apply the cut. The grinding-wheel is carried in a spindle head that is moved up and down by means of a handwheel during the actual grinding.

Water under pressure is supplied by a gear pump at the rear of the machine, driven by a large belt. The wheel-spindle bearings are not injured by loose abrasive, since this is continually washed away by the waste water from the turbine wheel. During the grinding, it is necessary to enclose the work by a guard and to cover the top of the gear with a plate.

This machine is described and illustrated in a recently published description[1] of the Saurer works. In the same article is a description of a special milling-head for roughing the bearing seats for motor-truck transmission cases. This head mounts two arbors, overhanging from a central bearing and driven by a separate motor. On the four projecting ends of the arbors are mounted a total of 21 milling-cutters, arranged for milling seven half-bearings simultaneously. The cutters are arranged in groups of three, one of which roughs out the bearing bore while two others face the ends. Additional bearings are provided on the fixture to support the cutters that are farthest from the central head.

Reaming is employed in the final finish of the bearings in the transmission case. A special reaming-fixture is employed, in which all the bores are finished by piloted reamer-bars.

[1] See *The Automobile Engineer*, August, 1928, p. 274.

Gear Grinding

PRODUCERS of gears will be interested in the paper by H. F. L. Orcutt, on p. 283 of this issue of THE JOURNAL. Of particular interest to production men are the opinions on different methods of grinding gears, as given in the discussion of this paper.

Standardization Activities

Leaf-Spring Standards

Subdivision Consolidates and Revises Present Spring and Spring-Parts Specifications

FOR some months a Subdivision of the Passenger-Car Division has been formulating a revision of the present Leaf-Spring Specifications, pp. 309 to 319 inclusive of the 1928 edition of the S.A.E. HANDBOOK. It has recommended that the following existing standards and recommended practices be cancelled: Leaf-Spring Nomenclature, Leaf Points, Finish of Springs, Wrapped Spring-Eyes, Leaf-Spring Definitions, Leaf-Spring Nibs and Shrunk Center-Bands.

The present specifications on Tests for Parallelism of Spring Eyes, Spring-Eye Bushings and Width of Spring-Ends have been incorporated in the proposed recommended practice. The present S.A.E. Standard on Spring Center-Bolts and the S.A.E. Recommended Practice on Spring Rebound-Clips, Spacers and Bolts will be slightly revised at a later date to conform to present practice and requirements of the industry.

As part of the proposed recommended practice a leaf-spring specification form, as illustrated, has been made a part of the specification.

The proposed Recommended Practice as it will be submitted to the Passenger-Car Division is as follows:

LEAF-SPRINGS

(*S.A.E. Recommended Practice*)

All letter dimensions refer to the Leaf-Spring Specification Form herewith.

Load.—Load is the force in pounds to be applied by the testing machine to the spring in question. Load is to be read on the testing machine after rapping the spring.

Height.—See dimension E.

Clearance.—Clearance is the greatest distance in inches the spring may deflect after specified load has been applied.

Opening.—See dimension F.

Where the exposed surface of the main leaf comes below the center line of the spring eyes, when spring is in the position illustrated, the dimension F shall be expressed as a minus quantity.

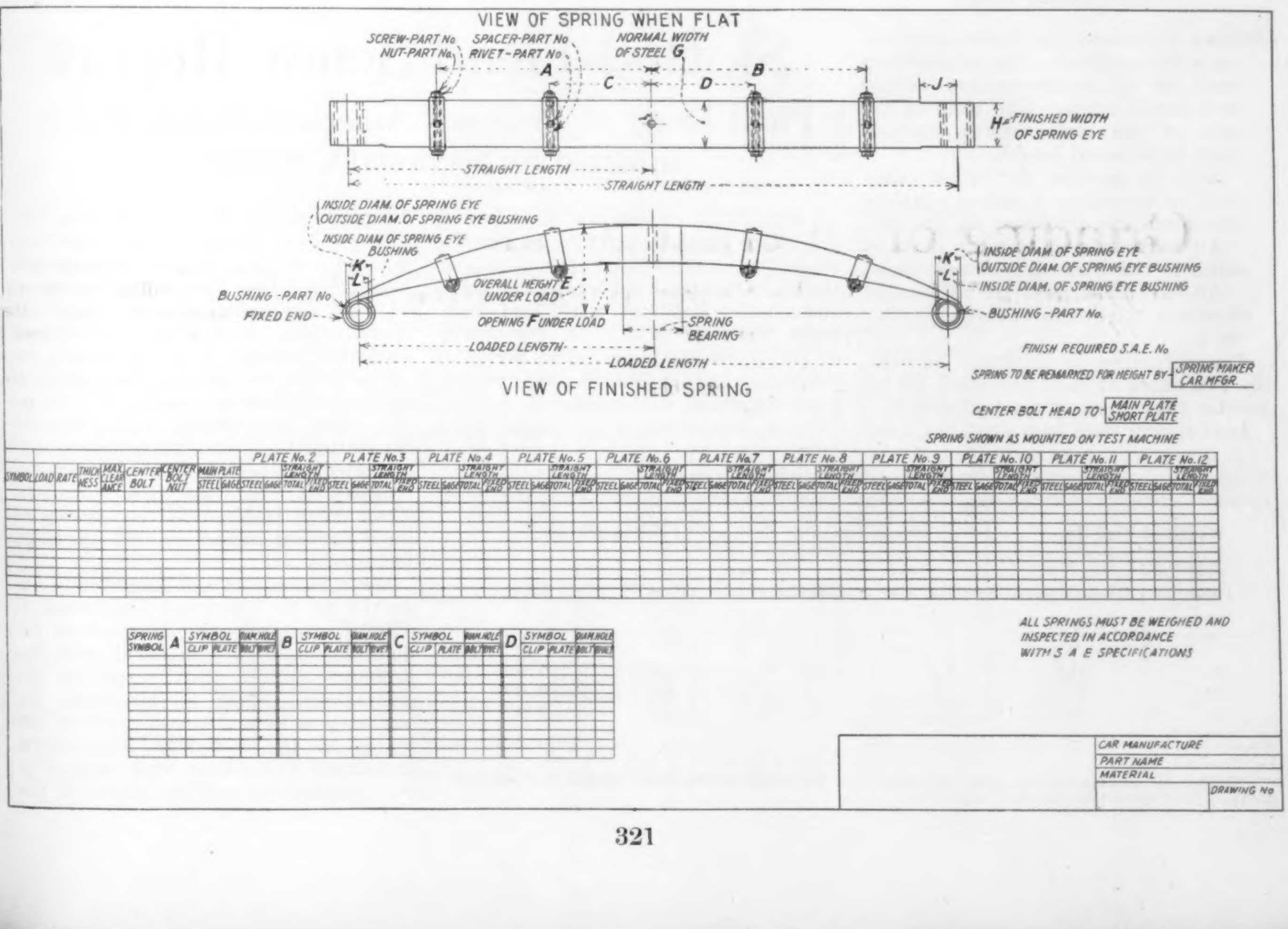
Rate (or Flexibility).—Rate is ½ the force, measured in pounds, necessary to deflect the spring from F plus 1 in. to F minus 1 in.

Finish.—Finish refers to the surface condition of the steel after heat-treatments.

Finish No. 1.—Leaves shall be left in the same condition as that in which they come from the heat-treating process.

Finish No. 2.—All burrs on the bearing sides of the leaves shall be removed.

Finish No. 3.—The sheared and trimmed edges of the leaves shall be chamfered on their bearing sides.



Finish No. 4.—All loose scale shall be removed.

Combinations of these numbers may be used to indicate the complete finish desired.

Leaf Numbers.—Leaves shall be designated by their numbers, number-one leaf being the main leaf; number-two leaf being the leaf above and adjacent to it; and so on.

Nominal Width of Spring Steel.—See dimension G.

Finished Width of Spring Steel.—See dimension H.

Spring-ends shall be finished to a width of 1/16 in. less than the nominal width of the springs, with a plus or minus tolerance of 0.005 in. for passenger-cars and 0.010 in. for motor-trucks, to a point far enough back on the spring to allow free shackle-movement or free sliding movement in case of flat-end springs.

Spring Eyes and Bushings.—See dimensions K and L.

TOLERANCES ON SPRING EYES AND BUSHINGS

Part	Diameter Tolerance, In.	
Bushed eyes	−0.001	−0.003
Unbushed eyes	+0.001	−0.004

The nominal wall-thickness of spring-eye bushings shall be 1/8 in. for all sizes of bushing.

Leaf-Spring Steel

Rolling Tolerances for Automobile Concave Spring-Steel.—The finished bars shall be of double-concave section with round edges. The radii of the arcs of the two concave surfaces shall be of equal length.

Rolls to produce the round edges shall be turned to a radius equal to two-thirds the thickness of the bar.

All bars ordered to gage shall be rolled to the Birmingham wire gage.

All bars must meet the width and thickness tolerances specified in Table 1.

The difference in thickness between the two edges of each bar shall not be greater than those given in Table 2.

Leaf-spring steel bars shall not have more than 1-in. curvature in 20 ft., or 1¼ in. in 25 ft., or 1½ in. in 30 ft.

TABLE 1—WIDTH AND THICKNESS TOLERANCES

Width of Flat, In.		Width, In.		Thickness[1], In.	
Over	To Inclusive	Plus	Minus	Plus	Minus
0	2¼	1/32	0	0.005	0.005
2¼	3	3/64	0	0.006	0.006
3	5	1/16	0	0.007	0.007

[1] Thickness measurements shall be taken at the edge of the bar where the concave surface intersects the rounded edge.

TABLE 2—DIFFERENCES IN THICKNESS

Width of Flat, In.		Difference in Thickness, In.
Over	To, Inclusive	
0	2	0.002
2	3	0.003
3	5	0.003

The concavity, or difference between the thickness at the edges and at the center of the bar, shall be as specified in Table 3.

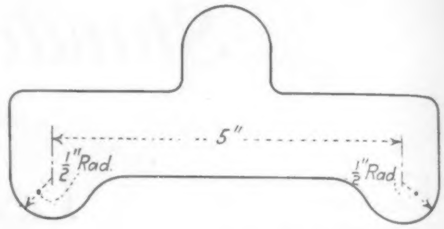
LEAF-SPRING TESTS

All leaf-springs shall be tested in an upright position and supported so as to permit free movement.

TABLE 3—ALLOWABLE VARIATIONS IN CONCAVITY

Width	Nominal Concavity	Maximum Concavity	Minimum Concavity
1½	0.007	0.009	0.004
1¾	0.008	0.010	0.005
2	0.010	0.012	0.006
2¼	0.011	0.013	0.007
2½	0.013	0.015	0.009
3	0.016	0.018	0.012
3½	0.018	0.020	0.013
4	0.021	0.023	0.016
5	0.029	0.031	0.023

All dimensions in inches.

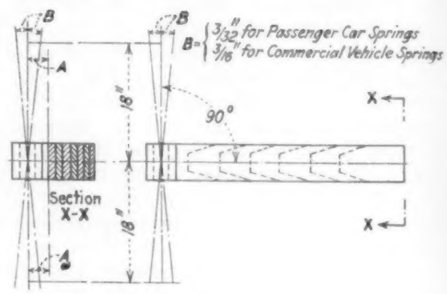


All tests or inspection measurements shall be made after rapping the leaf-spring in the test or inspection position.

TESTS FOR PARALLLELISM OF SPRING EYES

Eyes of main leaves shall be parallel and square (within specified limits) to the main leaf and parallel to each other.

The test shall be made by inserting two 3-ft. bars in the eyes as shown.



Slotted-Head Screw Report

Final Draft of Proposed American Standard Formulated by Sectional Committee

A PROJECT of interest to probably every manufacturer of automotive apparatus contemplates the standardization of slotted-head screws for metal and wood. It is the subject of a report, most of which is reproduced on the following pages. The Sectional Committee under which this project was authorized was organized in 1922, and the Subcommittee on Slotted-Head Proportions for Machine Screws, Cap Screws and Wood Screws was appointed and started its work shortly thereafter. The first tentative report of the Subcommittee was issued in March, 1924, but a number of difficult problems relating to it arose that resulted in further study by the Subcommittee. Additional drafts of the report have been issued since then for review by the Committee members and a limited number of other interests not represented on the Subcommittee. These have resulted in the issuing of the following report as the proposed final draft.

When the report has been finally approved by the Sectional Committee, it will be submitted to the sponsors for their approval in accordance with the procedure within their respective organizations. When so approved, the last step will be the approval of the report by the American Engineering Standards Committee with regard to the organization and procedure of the

Flat Head Machine Screws

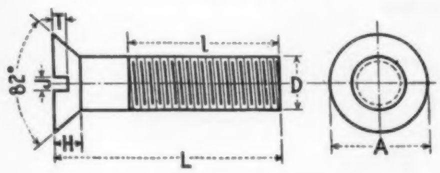


Table No. 1 Head Dimensions

	D	A		H		J		T	
Nominal Size	Max. Diameter	Head Diameter		Height of Head		Width of Slot		Depth of Slot	
		Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
2	.086	.172	.156	.051	.040	.036	.024	.023	.015
3	.099	.199	.181	.059	.048	.038	.026	.027	.017
4	.112	.225	.207	.067	.055	.040	.028	.030	.020
5	.125	.252	.232	.075	.062	.043	.031	.034	.022
6	.138	.279	.257	.083	.069	.045	.033	.038	.024
8	.164	.332	.308	.100	.084	.050	.037	.045	.029
10	.190	.385	.359	.116	.098	.055	.041	.053	.034
12	.216	.438	.410	.132	.112	.059	.045	.060	.039
¼	.250	.507	.477	.153	.131	.066	.051	.070	.046
5/16	.3125	.636	.600	.192	.166	.077	.061	.088	.058
⅜	.375	.762	.722	.230	.200	.088	.072	.106	.070

All dimensions in inches.

Note 1. Minimum (D) will be same as Minimum Outside Thread Diameter given in American Standard Screw Thread Report, Free Fit, (Class 2), when diameter and threads per inch are the same

Formulas

Head Diameter:
Maximum A = 2.040 D — 0.003
Minimum A = 1.960 D — 0.013

Height of Head:
Maximum H = 0.619 D — 0.002
Minimum H = 0.552 D — 0.007

Width of Slot:
Maximum J = 0.182 D + 0.020
Minimum J = 0.164 D + 0.010

Depth of Slot:
Maximum T = 0.288 D — 0.002
Minimum T = 0.192 D — 0.002

Countersink Angle:
Maximum 82 deg.
Minimum 80 deg.

Round Head Machine Screws

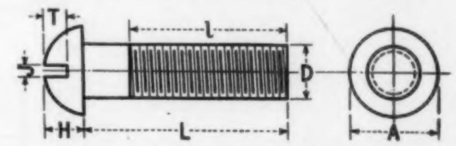


Table No. 2 Head Dimensions

	D	A		H		J		T	
Nominal Size	Max. Diameter	Head Diameter		Height of Head		Width of Slot		Depth of Slot	
		Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
2	.086	.162	.146	.070	.059	.036	.024	.048	.036
3	.099	.187	.169	.078	.067	.038	.026	.053	.040
4	.112	.211	.193	.086	.075	.040	.028	.058	.043
5	.125	.236	.217	.095	.083	.043	.031	.062	.047
6	.138	.260	.240	.103	.091	.045	.033	.067	.050
8	.164	.309	.287	.119	.107	.050	.037	.076	.057
10	.190	.359	.334	.136	.124	.055	.041	.086	.064
12	.216	.408	.382	.152	.140	.059	.045	.095	.071
¼	.250	.472	.443	.174	.161	.066	.051	.108	.080
5/16	.3125	.591	.557	.214	.200	.077	.061	.130	.097
⅜	.375	.708	.670	.254	.239	.088	.072	.153	.114

All dimensions in inches.

Note 1. Minimum (D) will be same as Minimum Outside Thread Diameter given in the American Standard Screw Thread Report, Free Fit, (Class 2), when diameter and threads per inch are the same.

Formulas

Head Diameter:
Maximum A = 1.887 D
Minimum A = 1.813 D — 0.010

Height of Head:
Maximum H = 0.636 D + 0.015
Minimum H = 0.624 D + 0.005

Width of Slot:
Maximum J = 0.182 D + 0.020
Minimum J = 0.164 D + 0.010

Depth of Slot:
Maximum T = 0.362 D + 0.017
Minimum T = 0.268 D + 0.013

Shape of Head:—Semi-elliptical.

Oval Head Machine Screws

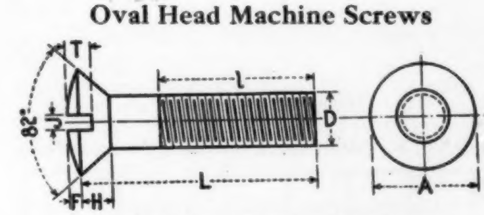


Table No. 3 Head Dimensions

	D	A		H		J		T		F		F+H	
Nominal Size	Max. Diameter	Head Diameter		Height of Head		Width of Slot		Depth of Slot		Height of Oval		Total Height of Head	
		Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
2	.086	.172	.156	.051	.040	.036	.024	.045	.037	.029	.022	.080	.063
3	.099	.199	.181	.059	.048	.038	.026	.052	.043	.033	.026	.092	.073
4	.112	.225	.207	.067	.055	.040	.028	.059	.049	.037	.029	.104	.084
5	.125	.252	.232	.075	.062	.043	.031	.067	.055	.041	.033	.116	.095
6	.138	.279	.257	.083	.069	.045	.033	.074	.060	.045	.036	.128	.105
8	.164	.332	.308	.100	.084	.050	.037	.088	.072	.053	.043	.152	.126
10	.190	.385	.359	.116	.098	.055	.041	.103	.084	.061	.050	.176	.148
12	.216	.438	.410	.132	.112	.059	.045	.117	.096	.069	.057	.200	.169
¼	.250	.507	.477	.153	.131	.066	.051	.136	.112	.079	.066	.232	.197
5/16	.3125	.636	.600	.192	.166	.077	.061	.171	.141	.098	.083	.290	.249
⅜	.375	.762	.722	.230	.200	.088	.072	.206	.170	.117	.100	.347	.300

All dimensions in inches.

Note 1. Minimum (D) will be same as Minimum Outside Thread Diameter given in American Standard Screw Thread Report, Free Fit, (Class 2), when diameter and threads per inch are the same.

Formulas

Head Diameter:
Maximum A = 2.04 D — 0.003
Minimum A = 1.96 D — 0.013

Height of Head:
Maximum H = 0.619 D — 0.002
Minimum H = 0.552 D — 0.007

Countersink Angle:
Maximum 82 deg.
Minimum 80 deg.

Width of Slot:
Maximum J = 0.182 D + 0.020
Minimum J = 0.164 D + 0.010

Depth of Slot:
Maximum T = 0.556 D — 0.003
Minimum T = 0.460 D — 0.003

Total Height of Head:
Max. (F + H) = Max. F + Max. H = 0.923 D + 0.001
Min. (F + H) = Min. F + Min. H = 0.820 D — 0.008

Fillister Head Machine Screws

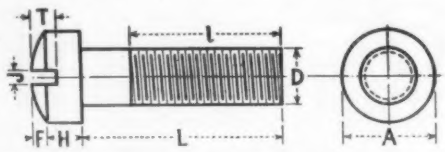


Table No. 4 Head Dimensions

Nominal Size	D	A		H		J		T		F		F+H	
	Max. Diameter	Head Diameter		Height of Head		Width of Slot		Depth of Slot		Height of Oval		Total Height of Head	
		Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
2	.086	.140	.124	.055	.045	.036	.024	.037	.021	.028	.018	.083	.063
3	.099	.161	.145	.063	.052	.038	.026	.043	.026	.032	.021	.095	.073
4	.112	.183	.166	.072	.060	.040	.028	.048	.031	.035	.024	.107	.084
5	.125	.205	.187	.081	.068	.043	.031	.054	.036	.039	.027	.120	.095
6	.138	.226	.208	.089	.076	.045	.033	.060	.041	.043	.029	.132	.105
8	.164	.270	.250	.106	.091	.050	.037	.071	.050	.050	.035	.156	.126
10	.190	.313	.292	.123	.107	.055	.041	.083	.060	.057	.041	.180	.148
12	.216	.357	.334	.141	.123	.059	.045	.094	.070	.064	.047	.205	.169
¼	.250	.414	.389	.163	.143	.066	.051	.109	.083	.074	.054	.237	.197
5/16	.3125	.519	.490	.205	.181	.077	.061	.137	.106	.092	.068	.297	.249
⅜	.375	.622	.590	.246	.218	.088	.072	.164	.129	.109	.082	.355	.300

All dimensions in inches.
Note 1 Minimum (D) will be same as Minimum Outside Thread Diameter given in American Standard Screw Thread Report, Free Fit, (Class 2), when diameter and threads per inch are the same

Formulas

Head Diameter:
Maximum $A = 1.670\,D - 0.004$
Minimum $A = 1.610\,D - 0.014$

Height of Head (Side):
Maximum $H = 0.660\,D - 0.002$
Minimum $H = 0.600\,D - 0.007$

Total Height of Head:
Max. $(F + H) =$ Max. F + Max. H
Min. $(F + H) =$ Min. F + Min. H

Width of Slot:
Maximum $J = 0.182\,D + 0.020$
Minimum $J = 0.164\,D + 0.010$

Depth of Slot:
Maximum $T = 0.440\,D - 0.001$
Minimum $T = 0.374\,D - 0.011$

Height of Oval:
Maximum $F = 0.280\,D + 0.004$
Minimum $F = 0.220\,D - 0.001$

Machine Screws

Table No. 5 Preferred Screw Lengths and Heads

Nominal Size	2	3	4	5	6	8	10	12	¼	5/16	⅜	2	3	4	6	8	10	12	¼	5/16	⅜
Length in Inches L	COARSE THREAD SERIES, FREE FIT, (Class 2) (Common Pitches) Threads per Inch											FINE THREAD SERIES, FREE FIT, (Class 2) (Less Common Pitches) Threads per Inch									
	56	48	40	40	32	32	24	24	20	18	16	64	56	48	40	36	32	28	28	24	24
⅛	FRP	FRP	FRP	RP	RP	RP						FR	FRP	FRP	RP						
3/16	FROP	FROP	FROP	FRP	FROP	FRP	RP					FR	FRP	FRP	RP	RP	R				
¼	FROP	FROP	FROP	FRP	FROP	FROP	FROP	RP				FR	FRP	FRP	FRP	FRP	FROP				
5/16	FRP	FRP	FROP	FRP	FROP	FROP	FROP	FRP	FRP			FR	FR	FRP	FRP	FRP	FROP	F	F		
⅜	FRP	FRP	FROP	FRP	FROP	FROP	FROP	FROP	FRP			F	FR	FRP	FROP	FROP	FROP	FROP	FR		
7/16	FRP	FRP	FROP	FRP	FROP	FROP	FROP	FROP	FRP			F	FR	FRP	FROP	FROP	FROP	FROP	FR		
½	FRP	FRP	FROP	FRP	FROP	FROP	FROP	FROP	FROP	FROP	FRP	F	FR	FRP	FROP	FROP	FROP	FROP	FR	R	
⅝	FRP	FRP	FROP	FRP	FROP	FROP	FROP	FROP	FROP	FROP	FRP		R	FR	FRP	FROP	FROP	FROP	FRP	FRP	FR
¾	FR	FR	FRP	FRP	FROP	FROP	FROP	FROP	FROP	FROP	FROP		R	FR	FRP	FROP	FROP	FROP	FRP	FRP	FR
⅞	R	R	FRP	FRP	FROP	FROP	FROP	FROP	FROP	FROP	FROP				FROP	FROP	FROP	FRP	FRP	FRP	FR
1			FRP	FRP	FROP	FROP	FROP	FROP	FROP	FRP	FRP				FR	FROP	FROP	FRP	FRP	FR	FR
1¼			R	FR	FROP	FROP	FROP	FROP	FROP	FRP	FRP				FR	FRP	FROP	FRP	FRP	FR	F
1½			R	FR	FROP	FROP	FROP	FROP	FROP	FRP	FRP				R	FR	FROP	FRP	FRP	F	F
1¾				F	FROP	FROP	FROP	FROP	FROP	FRP	FRP					F	FROP	FRP	FRP	F	F
2					FROP	FROP	FROP	FROP	FROP	FRP	FRP					F	FROP	FROP	FRP	F	F
2¼					R	FRP	FRP	FRP	FROP	FRP	FRP					F	FRP	FR	FR	F	F
2½						FR	FRP	FRP	FRP	FRP	FRP					F	FRP	F	F	F	F
2¾						FR	FR	FR	FRP	FRP	FRP					F	FRP	F	F	F	F
3						FR	FR	FR	FRP	FRP	FRP					F	FRP	F	F	F	F

All dimensions in inches.
Note 1. The table of screw lengths reproduced above is intended only as a guide to the users of these screws. A number of the listed sizes and lengths will not be regularly stocked by the manufacturers but will be available on order of a sufficient quantity. Letters in the vertical column under the nominal screw sizes indicate the style of head for that particular length; hence, F = Flat Head, R = Round Head, O = Oval Head, P = Fillister Head.
Note 2. Tolerance in length (L) = — 3 per cent. But not less than — .025 inches.
Note 3. Where length of screw (L) is 1¼ inches or less, the length of thread (l) will extend to as near the head as is practicable. Where the length of screw is over 1¼ inches, the thread length shall be not less than 1¼ inches.

Flat Head Cap Screws

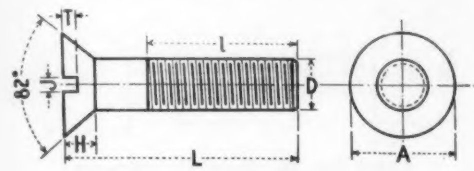


Table No. 6 Head Dimensions

Nominal Size	D	A		H	J		T	
	Max. Diameter	Head Diameter		Height of Head	Width of Slot		Depth of Slot	
		Maximum	Minimum	Nominal	Maximum	Minimum	Maximum	Minimum
1/4	.250	1/2	.477	.146	.070	.058	.073	.053
5/16	.3125	5/8	.598	.183	.079	.065	.091	.066
3/8	.375	3/4	.719	.220	.088	.074	.110	.080
7/16	.4375	13/16	.780	.220	.098	.083	.110	.075
1/2	.500	7/8	.841	.220	.110	.094	.110	.070
9/16	.5625	1	.962	.256	.123	.106	.128	.083
5/8	.625	1 1/8	1.083	.293	.138	.119	.146	.096
3/4	.750	1 3/8	1.326	.366	.154	.134	.183	.123

All dimensions in inches.

Note 1. Minimum (D) will be same as Minimum Outside Thread Diameter given in American Standard Screw Thread Report, Free Fit, (Class 2).

Formulas

Head Diameter:
- Maximum A = Nominal (No formula)
- Minimum A = Maximum A — (.03 Max. A + .008)

Height of Head:
- Nominal H = Computed from Maximum D and Maximum A, with 81 deg. (mean) angle. Nominal H, subject to variations in A and D and angle.

Width of Slot:
- Nominal J = .160 D + .024 = S (Approx. Cutter Width)
- Maximum J = S + (.05 S + .003)
- Minimum J = S — (.05 S + .003)

Depth of Slot:
- Maximum T = 0.500 H Nominal
- Minimum T = Maximum T — .08 D

Countersink Angle:
- Maximum 82 deg.
- Minimum 80 deg.

Button Head Cap Screws

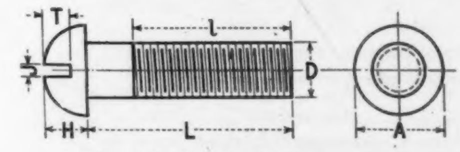


Table No. 7 Head Dimensions

Nominal Size	D	A		H		J		T	
	Max. Diameter	Head Diameter		Height of Head		Width of Slot		Depth of Slot	
		Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
1/4	.250	7/16	.418	.191	.175	.070	.058	.117	.097
5/16	.3125	9/16	.541	.246	.226	.079	.065	.151	.126
3/8	.375	5/8	.602	.273	.251	.088	.074	.167	.137
7/16	.4375	3/4	.725	.328	.302	.098	.083	.202	.167
1/2	.500	13/16	.786	.355	.328	.110	.094	.219	.179
9/16	.5625	15/16	.908	.410	.379	.123	.106	.253	.208
5/8	.625	1	.970	.438	.405	.138	.119	.270	.220
3/4	.750	1 1/4	1.215	.547	.506	.154	.134	.337	.277

All dimensions in inches.

Note 1. Minimum (D) will be same as Minimum Outside Thread Diameter given in American Standard Screw Thread Report, Free Fit (Class 2).

Formulas

Head Diameter:
- Maximum A = Nominal (No formula)
- Minimum A = Maximum A — (.02 Max. A + .010)

Height of Head:
- Maximum H = 7/16 Maximum A
- Minimum H = Maximum H — (0.03 Max. A + .003)

Width of Slot:
- Nominal J = .160 D + .024 = S (Approx. Cutter Width)
- Maximum J = S + (.05 S + .003)
- Minimum J = S — (.05 S + .003)

Depth of Slot:
- Maximum T = 2/3 Minimum H
- Minimum T = Maximum T — .08 D

Shape of Head: Semi-elliptical.

Fillister Head Cap Screws

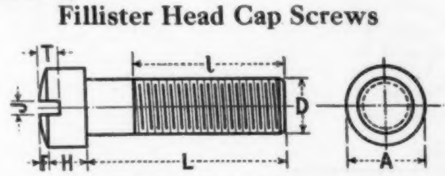


Table No. 8 Head Dimensions

Nominal Size	D	A		H		J		T		F		F+H	
	Max. Diameter	Head Diameter		Height of Head		Width of Slot		Depth of Slot		Height of Oval		Total Height of Head	
		Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
1/4	.250	3/8	.363	11/64	.157	.070	.058	.097	.077	.044	.038	.216	.195
5/16	.3125	7/16	.424	13/64	.186	.079	.065	.115	.090	.050	.044	.253	.230
3/8	.375	9/16	.547	1/4	.229	.088	.074	.142	.112	.064	.056	.314	.285
7/16	.4375	5/8	.608	19/64	.274	.098	.083	.168	.133	.071	.063	.368	.337
1/2	.500	3/4	.731	21/64	.301	.110	.094	.188	.148	.084	.075	.412	.376
9/16	.5625	13/16	.792	3/8	.347	.123	.106	.214	.169	.091	.081	.466	.428
5/8	.625	7/8	.853	27/64	.392	.138	.119	.240	.190	.099	.088	.521	.480
3/4	.750	1	.976	1/2	.466	.154	.134	.283	.233	.112	.100	.612	.566
7/8	.875	1 1/8	1.098	19/32	.556	.173	.151	.334	.264	.126	.113	.720	.669
1	1.000	1 5/16	1.282	21/32	.613	.194	.170	.372	.292	.146	.131	.802	.744

All dimensions in inches.
* Variation in height of oval.

Note 1. Minimum (D) will be same as Minimum Outside Thread Diameter given in American Standard Screw Thread Report, Free Fit, (Class 2).

Formulas

Head Diameter:
- Maximum A = Nominal (No formula)
- Minimum A = Maximum A — (.02 Max. A + .004)

Height of Head (Side):
- Maximum H = 2/3 D to nearest 64th inch
- Minimum H = Maximum H — (0.03 Max. A + .004)

Height of Oval:
- Maximum F = 0.110 Maximum A + .002
- Minimum F = 0.100 Maximum A

Width of Slot:
- Nominal J = .160 D + .024 = S (Approx. Cutter Width)
- Maximum J = S + (.05 S + .003)
- Minimum J = S — (.05 S + .003)

Depth of Slot:
- Maximum T = 0.50 (Minimum F + Minimum H)
- Minimum T = Maximum T — .08 D

Total Height of Head:
- Maximum (F + H) = Max. F + Max. H
- Minimum (F + H) = Min. F + Min. H

Formula for F included for purpose of determining tolerances for T and F, and are not to be used for inspection purposes.

Cap Screw Lengths

The length shall be measured from the largest diameter of the bearing surface of the Head to the extreme point, in a line parallel to the axis of the screw.

The difference between consecutive lengths of screws:

For screw lengths 1/4 in. to 1 in. shall be 1/8 in.
" " " 1 in. to 4 in. " " 1/4 in.
" " " 4 in. to 6 in. " " 1/2 in.

The tolerance in screw length shall be 3 per cent of the nominal length, with a minimum tolerance of .030 inch; one-third of the tolerance to be applied minus, and two-thirds plus.

Thread Lengths

Slotted Head Cap Screws shall be regularly threaded coarse pitch, and when so threaded shall have a length of thread equal to 2 D + 1/4 inch. Screws too short to allow the formula length of thread, may be threaded as close to the Head as practicable.

Screw Points

The points of all Cap Screws shall be flat, the flat being normal to the axis of the screw; and shall be chamfered at an angle of 35 deg. with the surface of the flat, -5 deg., -0 deg.; the chamfer to extend to the bottom of the thread. The edge of the chamfer is to be slightly rounded.

Round Head Wood Screws

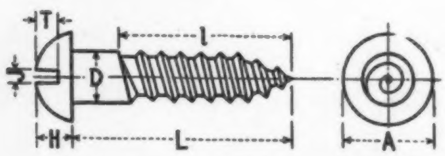


Table No. 9 Head Dimensions

Screw Number	D	A		H		J		T	
	Diameter	Head Diameter		Height of Head		Width of Slot		Depth of Slot	
		Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
0	.060	.113	.099	.053	.042	.031	.020	.039	.029
1	.073	.138	.122	.061	.051	.033	.022	.043	.033
2	.086	.162	.146	.070	.059	.036	.024	.048	.036
3	.099	.187	.169	.078	.067	.038	.026	.053	.040
4	.112	.211	.193	.086	.075	.040	.028	.058	.043
5	.125	.236	.217	.095	.083	.043	.031	.062	.047
6	.138	.260	.240	.103	091	.045	.033	.067	.050
7	.151	.285	.264	.111	.099	.047	.035	.072	.053
8	164	.309	.287	.119	.107	.050	.037	.076	.057
9	.177	.334	.311	.128	.115	.052	.039	.081	.060
10	.190	.359	.334	.136	.124	.055	.041	.086	.064
11	.203	.383	.358	.144	.132	.057	.043	.090	.067
12	216	.408	.382	.152	.140	.059	.045	095	.071
14	242	.457	.429	.169	.156	.064	.050	.105	.078
16	.268	.506	.476	.185	.172	.069	.054	.114	.085
18	.294	.555	.523	.202	.188	.074	.058	.123	.092
20	.320	.604	.570	.219	.205	.078	.062	.133	.099
24	.372	.702	.664	.252	.237	.088	.071	.152	.113

All dimensions in inches.

Tolerance in diameter (D) = + 0.004 to — 0.007 inches.

Formulas

Head Diameter:
Maximum A = 1.887 D
Minimum A = 1.813 D — 0.010
Height of Head:
Maximum H = 0.636 D + 0.015
Minimum H = 0.624 D + 0.005

Width of Slot:
Maximum J = 0.182 D + 0.020
Minimum J = 0.164 D + 0.010
Depth of Slot:
Maximum T = 0.362 D + 0.017
Minimum T = 0.268 D + 0.013
Shape of Head: Semi-elliptical.

Flat Head Wood Screws

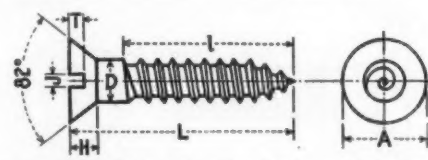


Table No. 10 Head Dimensions

Screw Number	D	A		H		J		T	
	Diameter	Head Diameter		Height of Head		Width of Slot		Depth of Slot	
		Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
0	.060	.119	.105	.035	.026	.031	.020	.015	.010
1	.073	.146	.130	.043	.033	.033	.022	.019	.012
2	.086	.172	.156	.051	.040	.036	.024	.023	.015
3	.099	.199	.181	.059	.048	.038	.026	.027	.017
4	.112	.225	.207	.067	.055	.040	.028	.030	.020
5	.125	.252	.232	.075	.062	.043	.031	.034	.022
6	138	.279	.257	.083	.069	.045	.033	.038	.024
7	.151	.305	.283	.091	.076	.047	.035	.041	.027
8	.164	.332	.308	.100	.084	.050	.037	.045	.029
9	.177	.358	.334	.108	.091	.052	.039	.049	.032
10	190	.385	.359	.116	.098	.055	.041	.053	.034
11	.203	.411	.385	.124	.105	.057	.043	.056	.037
12	.216	.438	.410	.132	.112	.059	.045	.060	.039
14	.242	.491	.461	.148	.127	.064	.050	.068	.044
16	.268	.544	.512	.164	.141	.069	.054	.075	.049
18	.294	.597	.563	.180	.155	.074	.058	.083	.054
20	.320	.650	.614	.196	.170	.078	.062	.090	.059
24	372	.756	.716	.228	.198	.088	.071	.105	.069

All dimensions in inches.

Tolerance in diameter (D) + 0.004 to — 0.007 inches.

Formulas

Head Diameter:
Maximum A = 2.04 D — 0.003
Minimum A = 1.96 D — 0.013
Height of Head:
Maximum H = 0.619 D — 0.002
Minimum H = 0.552 D — 0.007

Width of Slot:
Maximum J = 0.182 D + 0.020
Minimum J = 0.164 D + 0.010
Depth of Slot:
Maximum T = 0.288 D — 0.002
Minimum T = 0.192 D — 0.002

Countersink Angle:
Maximum 82 deg.
Minimum 80 deg.

Table No. 12 Length Tolerances of Round Head Wood Screws

Screw Number	Tolerance
0	.06
1	.07
2	.08
3	.08
4	.09
5	.10
6	.10
7	.11
8	.12
9	.13
10	.13
11	.14
12	.15
14	.16
16	.18
18	.20
20	.22
24	.27

Tolerances in inches.

Table No. 13 Maximum and Minimum Lengths of Flat and Oval Head Wood Screws

Nominal	Max.	Min.
1/4	.250	.22
3/8	.375	.34
1/2	.500	.46
5/8	.625	.59
3/4	.750	.71
7/8	.875	.83
1	1.000	.96
1 1/4	1.250	1.20
1 1/2	1.500	1.45
1 3/4	1.750	1.69
2	2.000	1.94
2 1/4	2.250	2.19
2 1/2	2.500	2.43
2 3/4	2.750	2.68
3	3.000	2.92
3 1/2	3.500	3.42
4	4.000	3.91
4 1/2	4.500	4.40
5	5.000	4.89

All dimensions in inches.

Oval Head Wood Screws

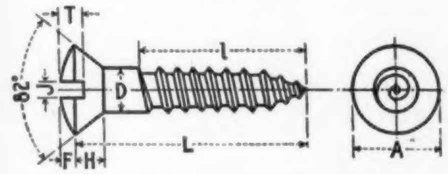


Table No. 11 Head Dimensions

	D	A		H		J		T		F		F+H	
Screw Number	Diameter	Head Diameter		Height of Head		Width of Slot		Depth of Slot		Height of Oval		Total Height of Head	
		Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
0	.060	.119	.105	.035	.026	.031	.020	.030	.025	.021	.015	.056	.041
1	.073	.146	.130	.043	.033	.033	.022	.038	.031	.025	.019	.068	.052
2	.086	.172	.156	.051	.040	.036	.024	.045	.037	.029	.022	.080	.063
3	.099	.199	.181	.059	.048	.038	.026	.052	.043	.033	.026	.092	.073
4	.112	.225	.207	.067	.055	.040	.028	.059	.049	.037	.029	.104	.084
5	.125	.252	.232	.075	.062	.043	.031	.067	.055	.041	.033	.116	.095
6	.138	.279	.257	.083	.069	.045	.033	.074	.060	.045	.036	.128	.105
7	.151	.305	.283	.091	.076	.047	.035	.081	.066	.049	.039	.140	.116
8	.164	.332	.308	.100	.084	.050	.037	.088	.072	.053	.043	.152	.126
9	.177	.358	.334	.108	.091	.052	.039	.095	.078	.057	.046	.164	.137
10	.190	.385	.359	.116	.098	.055	.041	.103	.084	.061	.050	.176	.148
11	.203	.411	.385	.124	.105	.057	.043	.110	.090	.065	.053	.188	.158
12	.216	.438	.410	.132	.112	.059	.045	.117	.096	.069	.057	.200	.169
14	.242	.491	.461	.148	.127	.064	.050	.132	.108	.077	.064	.224	.190
16	.268	.544	.512	.164	.141	.069	.054	.146	.120	.084	.071	.248	.212
18	.294	.597	.563	.180	.155	.074	.058	.160	.132	.092	.078	.272	.233
20	.320	.650	.614	.196	.170	.078	.062	.175	.144	.100	.085	.296	.254
24	.372	.756	.716	.228	.198	.088	.071	.204	.168	.116	.099	.344	.297

All dimensions in inches.

Tolerance in diameter (D) = + 0.004 to — 0.007 inches.

Formulas

Head Diameter:
Maximum A = 2.04 D — 0.003
Minimum A = 1.96 D — 0.013
Height of Head (Countersink):
Maximum H = 0.619 D — 0.002
Minimum H = 0.552 D — 0.007
Width of Slot:
Maximum J = 0.182 D + 0.020
Minimum J = 0.164 D + 0.010
Depth of Slot:
Maximum T = 0.556 D — 0.003
Minimum T = 0.460 D — 0.003
Height of Oval:
Maximum F = 0.304 D + 0.003
Minimum F = 0.268 D — 0.001
Total Height of Head:
Max. (F + H) = Max. F + Max. H = 0.923 D + 0.001
Min. (F + H) = Min. F + Min. H = 0.820 D — 0.008
Countersink Angle:
Maximum 82 deg.
Minimum 80 deg.

Brass Wood Screws

Table No. 14 Standard Screw Lengths and Heads

Screw Number	0	1	2	3	4	5	6	7
Nominal Length								
1/4	FRO	FRO	FRO	FRO	FRO			
3/8	FRO	FRO	FRO	FRO	FRO	FRO	FRO	
1/2		FRO	FRO	FRO	FRO	FRO	FRO	FRO
5/8			FRO	FRO	FRO	FRO	FRO	FRO
3/4			FRO	FRO	FRO	FRO	FRO	FRO
7/8					FRO	FRO	FRO	FRO
1					FRO	FRO	FRO	FRO
1 1/4							FRO	FRO
1 1/2							FRO	FRO
1 3/4								
2								

Screw Number	8	9	10	11	12	14	16	18
Nominal Length								
1/2	FRO							
5/8	FRO	FRO	FRO					
3/4	FRO	FRO	FRO	FR	FRO			
7/8	FRO	FRO	FRO	FR	FR			
1	FRO	FRO	FRO	FR	FRO	FRO		
1 1/4	FRO	FRO	FRO	FR	FRO	FRO		
1 1/2	FRO	FRO	FRO	FR	FRO	FRO		
1 3/4	FRO	FRO	FRO	FR	FRO	FRO		
2	FRO	FRO	FRO	FR	FRO	FRO	F	F
2 1/4			FR	FR	FR	FR	F	F
2 1/2			FR	FR	FR	FR	F	F
2 3/4								
3					FR	FR	F	F
3 1/2					F	F	F	F

All dimensions in inches.

Note 1. Letters in the vertical columns under screw members indicate the style of head for that particular length; hence, F = Flat Head, R = Round Head, O = Oval Head.

Steel Wood Screws

Table No. 15 Standard Screw Lengths and Heads

Screw Number	0	1	2	3	4	5	6	7	8
Nominal Length									
1/4	FR	FR	FR	FR	FR				
3/8	FR	FR	FR	FRO	FRO	FR	FR	FR	FR
1/2		FR	FR	FR	FRO	FRO	FRO	FRO	FRO
5/8			FR	FR	FRO	FRO	FRO	FRO	FRO
3/4			FR	FR	FRO	FRO	FRO	FRO	FRO
7/8				FR	FR	FR	FR	FRO	FRO
1				FR	FR	FRO	FRO	FRO	FRO
1 1/4					FR	FR	FRO	FRO	FRO
1 1/2					FR	FR	FRO	FRO	FRO
1 3/4							FRO	FRO	FRO
2							FR	FR	FR
2 1/4							FR	FR	FR
2 1/2							FR	FR	FR
2 3/4									FR

Screw Number	9	10	11	12	14	16	18	20	24
Nominal Length									
1/2	FR	FR							
5/8	FR	FR	FR	FR					
3/4	FRO	FRO	FR	FR					
7/8	FRO	FRO	FR	FRO	FR				
1	FRO	FRO	FRO	FRO	FRO	FR			
1 1/4	FRO	FRO	FRO	FRO	FRO	FR	FR		
1 1/2	FRO	FRO	FRO	FRO	FRO	FRO	FRO	FRO	
1 3/4	FRO	FRO	FRO	FRO	FRO	FRO	FRO	FRO	
2	FR	FRO	FRO	FRO	FRO	FRO	FRO	FRO	
2 1/4	FR	FR	FR	FRO	FRO	FR	F	F	
2 1/2	FR	FR	FR	FRO	FRO	FR	FR	FR	
2 3/4	FR	FR	F	FR	FR	F	F	F	
3	FR	FR	F	FR	FR	FR	FR	F	F
3 1/2		FR	F	FR	FR	FR	F	F	F
4				FR	FR	FR	F	F	F
4 1/2					F	F	F	F	F
5					F	F	F	F	F

All dimensions in inches.

Note 1. Letters in the vertical columns under screw members indicate the style of head for that particular length; hence, F = Flat Head, R = Round Head, O = Oval Head.

Sectional Committee. Then the report will be printed in pamphlet form for distribution through the sponsors.

Of Importance to the Industry

This standardization of slotted-head screws is as important to the automotive industry and the other mechanical industries as was the standardization of screw-threads and their several classes of fit that has already been completed. Probably no other single article is manufactured and used in such quantities as are the screws in these classes. Therefore it is particularly important that the standard, when issued, shall be acceptable to all industries. The standardization affects very materially the screw manufacturers and users. The head dimensions have been based on formulas established for each type of screw. The widths of the slots are the same for each type of machine screw, cap screw and wood screw, but the slot depths vary for each type of screw-head.

One suggestion received regarding the report is that the overlapping sizes of the machine screws and cap screws are so nearly alike that they might well be combined into a single list. Another feature is the difference in the method of expressing the length tolerances between the round-head wood-screws and the flat and oval-head wood-screws as shown in Tables 12 and 13. These points are illustrative of features of the report that should be studied, together with the detail dimensions, to assure that when finally adopted the standard will be satisfactory and acceptable to all industries concerned.

Criticism and Comment Wanted

The report is published substantially in full herewith so that all members of the Society may review it. Any criticisms or comments should be sent to the Society's Standards Department promptly, to be referred to the Subcommittee and the Sectional Committee before they vote finally on the report.

The Society's representatives on the Sectional Committee are J. A. Anglada, of the Anglada Motor Corp.; A. Boor, of the Willys-Overland Co.; A. H. Gilbert, of the Rock Island Plow Co.; M. C. Horine, of the International Motor Co.; and W. J. Outcalt, of the General Motors Corp.

To Study Aircraft Lighting

Tests in Progress for Report to Proposed Aeronautic Division Subcommittee

An important feature of the design of commercial aircraft, that has a direct bearing on their safe operation in flying to avoid collision and in landing to avoid danger of crack-ups, is that of adequate and proper lighting-equipment on the plane. The Aeronautic Division of the Society's Standards Committee has received the suggestion that a careful study be made of this subject with a view to establishing standardization of airplane lighting-equipment and its arrangement on the plane.

Preliminary tests are in progress by L. E. Lighton, a member of the Standards Committee, on commercial airplanes that are being built, with the intention of placing the resulting data in the hands of a Subdivision of the Aeronautic Division of the Standards Committee that will probably be organized.

Requirements of a general nature for the lighting equipment of airplanes is referred to under Section 42, Articles 420 to 424 inclusive, of the Aeronautic Safety Code formulated under the procedure of the American Engineering Standards Committee and sponsored by the Society and the Bureau of Standards. This code was finally approved and issued in the latter part of 1925 and, by its provisions, recognized the growing need at that time for the development of adequate and proper lighting-arrangements on airplanes. Undoubtedly it was too early at that time to attempt to establish definite recommendations or standardization in this connection, but it is felt that, with the rapid progress made within the last two or three years in the design and operation of commercial aircraft, the formulation of definite standards for aircraft lighting has now become a necessity. The establishing now of definite sound practice in airplane lighting will avoid, in a very large measure at least, an unnecessary variety of systems of lighting arrangement that would be dangerous in the operation of aircraft traffic. The case is analogous to the arrangement of lights in marine transportation, which are thoroughly standardized and well understood throughout the world.

Proposed Split-Rivet Slot Depths

Continuing the work which the Subdivision on Rivets has been doing on the subject of split and tubular rivets, a meeting was held on July 25 for the purpose of developing a table of slot depths for split rivets. In addition to this work, this committee has under consideration the development of hole diameters and depths for tubular rivets and the question of tolerances for head thicknesses and diameters for both types. It is also proposed to develop a table of exact body-diameters to supplement the present list of nominal sizes, so that users may have definite information as to the actual sizes of the rivets and the sizes of the holes necessary therefor. The following table of slot depths was approved by the Subdivision for submission to the Parts and Fittings Division as an addition to the present S.A.E. Standard on Split Rivets, p. 192, of the 1928 edition of the S.A.E. Handbook.

SPLIT RIVET SLOT DEPTHS

Body Diameter of Rivet, In.	Rivet Length, In.	Proposed Slot-Depth, In.
3/32	3/16 to 5/16 incl.	1/32 of head
	7/16 and 1/2	5/16
1/8	3/16 to 5/16 incl.	1/32 of head
	3/8	1/16 of head
9/64	7/16 to 3/4 incl.	5/16
	3/16 to 3/8 incl.	1/32 of head
	7/16	11/32
	1/2 to 3/4 incl.	13/32
3/16	1/4 and 5/16	1/32 of head
	3/8 to 11/16 incl.	1/16 of head
	3/4	5/8

The Subdivision personnel is being augmented by the addition of representatives of other rivet manufacturers, and of H. E. Maynard of the Chrysler Corporation, who has agreed to assist in this work. Other meetings will be held during the month of September in order that the proposed revisions may be put into final form before submission to the Parts and Fittings Division.

Rubber Bushings

Information has been collected on the utilization of rubber bushings covered by the present standard, p. 158 of the 1928 edition of the S.A.E. Handbook. Only 13 companies out of 44 use any of the sizes designated. Dimensions of the bushings specified by the remaining 31 companies have been reported.

In view of this situation, A. R. Lewellyn, chairman of the Electrical Equipment Division, has requested that a Subdivision, composed of rubber and cable manufacturers and representatives of the car companies, be organized to revise the present S.A.E. specifications to meet existing requirements and manufacturing practices. It is anticipated that such revision will be completed in time for presentation to the Standards Committee in January.

1928-1929 Section Officers

Men Who Have Been Preparing Plans for the Activities for the New Season

SECTION officers elected at the May and June meetings of the Sections have, during the summer months, been preparing the programs for the Section meetings for the coming official year. All meetings scheduled are listed in the calendar of S.A.E. meetings which appears each month on the second text page of THE JOURNAL.

The list of Section officers elected is given herewith, as the S.A.E. Roster lists the Section officers for the 1927-1928 administrative year.

The activities of the 13 Sections of the Society depend entirely upon the initiative and ability of the Section officers and the committees appointed. The Sections are very largely separate entities, having no direct connection with the parent Society except that their Constitutions are in harmony with that of the Society and that the membership is limited to individual members and Enrolled Students.

The parent Society assists a Section financially in case the Section income is not sufficient for its necessary and approved activities. Technical papers presented at Section meetings, if of sufficient general interest and merit, are

SECTION CHAIRMEN ON THE MAP FOR THE SECTION YEAR OF 1928-1929

Their Names and Their Sections Are: 1—E. W. Kimball, Buffalo; 2—J. W. Tierney, Chicago; 3—F. Jehle, Cleveland; 4—Opie Chenoweth, Dayton; 5—B. J. Lemon, Detroit; 6—F. S. Duesenberg, Indiana; 7—S. R. Dresser, Metropolitan; 8—Cyrus A. Cole, Milwaukee; 9—K. T. Brown, New England; 10—S. B. Shaw, Northern California; 11—A. Gelpke, Pennsylvania; 12—E. B. Moore, Southern California; and 13—Thomas T. Neill, Washington

published in due course in THE JOURNAL.

SECTION OFFICERS FOR CURRENT YEAR

BUFFALO

Chairman: E. W. Kimball, Vacuum Oil Co., Buffalo.
Vice-Chairman: Gustaf Carvelli, Curtiss Aeroplane & Motor Co., Inc., Buffalo.
Secretary: Donald S. Cox. Pierce-Arrow Motor Car Co., 1695 Elmwood Avenue, Buffalo.
Treasurer: William Edgar John, Buffalo Gasolene Motor Co., Buffalo.

CHICAGO

Chairman: J. W. Tierney, Electric Storage Battery Co., Chicago.
Vice-Chairman: D. P. Barnard, 4th, Standard Oil Co. of Indiana Engine Laboratory, Whiting, Ind.
Secretary: Lee W. Oldfield, Package-Car Corp., 1923 South Michigan Avenue, Chicago.
Treasurer: C. A. Buckbee, Marlin-Rockwell Corp., Gurney Division, Chicago.

CLEVELAND

Chairman: Ferdinand Jehle, White Motor Co., Cleveland.
Vice-Chairman: S. L. Bradley, Ross Gear & Tool Co., Cleveland.
Secretary: E. L. Allen, Chandler-Cleveland Motors Corp., Euclid Avenue and London Road, Cleveland.
Treasurer: H. F. Sauer, Electric Storage Battery Co., Cleveland.

DAYTON

Chairman: Opie Chenoweth, Air Corps, Dayton, Ohio.
Vice-Chairman: F. W. Heckert, Cincinnati Ball Crank Co., Dayton, Ohio.
Secretary: Paul F. Schenck, Board of Education, 707 North Broadway, Dayton, Ohio.
Treasurer: Norman N. Tilley, Air Corps, Dayton, Ohio.

DETROIT

Chairman: B. J. Lemon, United States Rubber Co., Detroit.
Vice-Chairman: L. C. Hill, Murray Corp. of America, Detroit.
Secretary: L. A. Chaminade, Studebaker Corp. of America, Detroit. (Mail: 5-110 General Motors Building.)
Treasurer: F. W. Marschner, New Departure Mfg. Co., Detroit.

INDIANA

Chairman: F. S. Duesenberg, Duesenberg, Inc., Indianapolis.
Vice-Chairman: George H. Freers, Marmon Motor Car Co., Indianapolis.
Secretary: Robert P. Lewis, Marmon Motor Car Co., 1101 West Morris Street, Indianapolis.
Treasurer: Charles A. Trask, Rockwood Mfg. Co., Indianapolis.

METROPOLITAN

Chairman: S. R. Dresser, Whitney-Blake Co., New York City.
Vice-Chairman: George A. Round, Vacuum Oil Co., New York City.
Secretary: W. H. Conant, New York Lubricating Oil Co. (Mail: Room 703, 29 West 39th Street, New York City.)
Treasurer: T. C. Smith, American Telephone & Telegraph Co., New York City.

MILWAUKEE

Chairman: C. L. Cole, Williams, Cole & Wolff, Inc., Milwaukee.
Vice-Chairman: A. C. Wollensak, Sterling Motor Truck Co., Milwaukee.
Secretary: Henry L. Debbink, Milwaukee Electric Railway & Light Co., Public Service Building, Milwaukee.
Treasurer: R. W. Ballentine, Timken Roller Bearing Co., Milwaukee.

NEW ENGLAND

Chairman: Knox T. Brown, Packard Motor Car Co. of Boston, Boston.
Vice-Chairman: George L. Appleyard, Robinson-Toohey Co., Lawrence, Mass.
Secretary: William M. Clark, S. S. Pierce Co., 133 Brookline Avenue, Boston.
Treasurer: Albert T. Lodge, Mohawk Chevrolet Co., Greenfield, Mass.

NORTHERN CALIFORNIA

Chairman: S. B. Shaw, Pacific Gas & Electric Co., San Francisco.
Vice-Chairman: Horace L. Hirschler, Horace Remote Control Co., San Francisco.
Vice-Chairman: Herbert Miller, Sterling Motor Truck Co. of California, Oakland, Cal.
Secretary: William S. Crowell, Home Accident Insurance Co., Syndicate Building, Oakland, Cal. (Mail: 1462 Waller Street, San Francisco.)
Treasurer: Fred L. Sargent, The White Co., San Francisco.

PENNSYLVANIA

Chairman: A. Gelpke, Autocar Co., Ardmore, Pa.
Vice-Chairman: J. H. Geisse, Naval Aircraft Factory, Navy Yard, Philadelphia.
Secretary: Charles C. Trump, Supplee-Wills-Jones Milk Co., 1523 North 26th Street, Philadelphia.
Treasurer: O. M. Thornton, Titeflex Metal Hose Co., Philadelphia.

SOUTHERN CALIFORNIA

Chairman: Eustace B. Moore, Los Angeles Automotive Works, Los Angeles.
Vice-Chairman: William H. Fairbanks, Southern California Telephone Co., Los Angeles.
Secretary: Fred C. Patton, Los Angeles Motor Coach Co., 1023 North Virgil Avenue, Los Angeles.
Treasurer: J. Jerome Canavan, Albertson Motors, Inc., Los Angeles.

WASHINGTON

Chairman: T. T. Neill, Bureau of Standards, City of Washington.
Vice-Chairman: G. O. Pooley, Chesapeake & Potomac Telephone Co., City of Washington.
Secretary: E. S. Pardoe, Capital Traction Co., 36th and M Streets, N. W., City of Washington.
Treasurer: G. E. Reynolds, City of Washington.

Brewer Designed Radial Engine in 1910

OWING to a regrettable typographical error, which was not caught by the proofreader, THE JOURNAL for June stated, in the report of the Pennsylvania Section meeting, that Capt. R. W. A. Brewer designed a fixed radial engine in 1921. Captain Brewer designed his first fixed radial air-cooled engine in 1910 and applied for British and French patents on important features of this type of engine in the same year.

Perhaps He Was!

The Society receives stenographic reports of all Section meetings, the Section meeting accounts as well as the discussion of papers being based on these reports.

In a recent report from a Western Section a speaker was credited with saying that the title of a certain paper would be "Adam, the Wonder Worker." The statement that the paper would be illustrated with slides, models and charts, only added to the interest.

The real title was "Atoms as Wonder Workers"!

Personal Notes of the Members

Society Members Honored by Aeronautical Chamber

News of the recent reorganization of the Aeronautical Chamber of Commerce and of the election of officers has special interest for members of the Society, as 12 of the 20 governors elected, including the president, Major Lester D. Gardner, belong to the Society. The reorganization calls for 21 governors, instead of 13 as formerly. One governor is yet to be selected.

It was announced in the daily press that the Chamber was reorganized to fit it to deal more adequately with National problems. The new plan provides for six geographical divisions in the United States, each to be under the direction of a vice-president, as well as for divisions based on specialized professional interest.

The 12 governors who are members of the Society are: S. S. Bradley, general manager of the Aeronautical Chamber of Commerce; C. J. Brukner, president of the Advance Aircraft Co.; C. H. Colvin, president and general manager of the Pioneer Instrument Co., Inc.; Sherman M. Fairchild, president of the Fairchild Aviation Corp.; Carl B. Fritsche, general manager of the Aircraft Development Corp.; Lester D. Gardner, president of Aeronautical Industries, Inc.; Paul Henderson, vice-president and general manager of National Air Transport, Inc.; J. C. Hunsaker, assistant vice-president of Bell Telephone Laboratories, Inc.; P. G. Johnson, president and general manager of the Boeing Airplane Co.; C. L. Lawrance, president of the Wright Aeronautical Corp.; C. T. Ludington, president of the B. B. T. Corp. of America, and Harold F. Pitcairn, president of Pitcairn Aviation, Inc.

H. I. Cone with Shipping Board

Rear Admiral H. I. Cone has recently been made Commissioner of the United States Shipping Board, in the City of Washington.

Graduated from the University of Florida in 1889 and from the United States Naval Academy in 1894, Rear Admiral Cone served in the United States Navy until he was retired in 1922 with the rank of rear admiral. One of his most noteworthy activities in the Navy was serving as marine superintendent of the Panama Canal. During the World War he was in command of the United States Naval Aviation Forces Foreign Service. Since his retirement from the Navy, he has been associated with the Daniel Guggenheim Fund for the Promotion of Aeronautics, in the capacity of vice-president and treasurer.

Rear Admiral Cone has been a Member of the Society since 1926. He is also a member of the American Society of Mechanical Engineers, the Society of Naval Architects and Marine Engineers, and the Society of Naval Engineers.

Wood Develops Interesting Press

Announcement was made recently of the development of what is claimed to be the fastest type of newspaper printing-press in the world, which is said to increase the speed and volume of newspaper production more than a full two-thirds, adding besides a new smoothness of performance. Its inventor is Henry A. Wise Wood, president of the Wood Newspaper Machinery Corp., of New York City.

Mr. Wood is known, not only as an inventor of improvements in newspaper printing machinery, but as a man who has been constructively interested in aeronautics for many years. He founded *Flying* and was its editor until 1918. He was governor of the Aero Club of America from 1911 to 1921, and its vice-president from 1915 to 1921. He was a founder member of the American Society of Aeronautic Engineers and became its president, holding that office until the organization was merged with the Society of Automotive Engineers. Mr. Wood has been a member of the Society since 1916.

Mr. Wood and Howard E. Coffin, with others, participated most actively in the merging of the American Society of Aeronautic Engineers and other organizations with the Society of Automobile Engineers, at the time the name of the last-named was changed to Society of Automotive Engineers, Inc. Mr. Wood suggested the use of the word "automotive" in this connection.

During the war Mr. Wood was a member of the Naval Consulting Board, having been named as the representative of the American Society of Aeronautic Engineers.

McArthur Becomes General Superintendent

A. S. McArthur, who has been connected with the Toronto Transportation Commission for several years, first as assistant superintendent of the motor coach department, later as superintendent of the garage department, has recently become general superintendent of the Commission.

Since receiving the degree of Bachelor of Science from the University of Toronto, Mr. McArthur was, prior to his connection with the Toronto Transportation Commission, successively a Dominion land surveyor, an assistant resident engineer with the National Transcontinental Railways, a resident engineer with the Toronto Civic Railways and, from 1915 to 1919, a lieutenant in the Canadian Engineers.

Mr. McArthur joined the Society in 1926 and has taken an active interest in the Society's work in the transportation field, besides being known to Society members through his professional achievements and his participation in the discussion at technical sessions.

Lester D. Seymour Promoted

Lester D. Seymour, who has been chief engineer of the National Air Transport, Inc., since 1926, has been made assistant general manager of that company.

After graduation from Syracuse University in 1916, Mr. Seymour was assistant engineer with the General Engineering & Management Corp. of New York City, from which he resigned to enter the United States Air Service. He took the military course in aeronautical engineering at the Massachusetts Institute of Technology during the early months of 1918 and pursued his aeronautical studies in Paris, France, in the spring of 1919. Returning to this Country, he remained with the Air Service, in the City of Washington, until 1926, when he became chief engineer of the National Air Transport, Inc., Chicago.

Mr. Seymour has been a Member of the Society since 1927. He gave a most interesting talk on The Practicability of Air Transport at the April, 1927, meeting of the Cleveland Section, and those members who attended the 1927 Transportation Banquet at Chicago had the pleasure of hearing him speak on Air Transport.

Lodge Makes New Connection

Albert Lodge has recently bought out the business of the Mohawk Chevrolet Co., at Greenfield, Mass. He has been service engineer with the Charles Street Garage Co., in Boston, for nearly a year, after a 12-year affiliation with the E. A. Patch Co., of the same city.

Mr. Lodge joined the Society in 1925 and has been active in the work of the New England Section since that year. He is now entering upon his third term as treasurer of the Section and is a member of the Sections Committee for the current year.

John W. Ackermans, who until lately was body engineer for the Fremont

(*Continued on* p. 34)

Roger Jouett Gilmore

AFTER several months' illness, during which he made a gallant fight and from which he seemed to be recovering, Roger Jouett Gilmore died on July 12 as the result of the overtax on his heart. At the time of his death he was a member of the firm of Gilmore & Co., investment bankers of Boston, and a resident of Newton Highlands, Mass.

Mr. Gilmore was born at Cambridge, Mass., in 1886, and acquired his technical education at Harvard University, graduating in 1909 with the degree of Bachelor of Arts and qualified also as Bachelor of Science. He was an instructor in civil engineering at Harvard University and at the Harvard engineering camp in 1908 and assistant instructor in aerodynamics at Columbia University in 1915. With the exception of one year, he was connected with the Packard Motor Car Co. and its branches from 1909 to 1919, first at the factory in the assembling and testing departments. After spending five months in gaining a specific knowledge of Packard cars, he went to the company's Philadelphia branch as trouble finder on the road, and in the next four years progressively became a salesman, sales manager and assistant general manager.

From the middle of 1914, Mr. Gilmore was for a year president of the American Chemical Co. and of Wilson & Wilson. He was next sales manager for the Packard Motor Car Co. of Boston and was then transferred to the New York City branch as territorial manager in charge of branches. In the next four years he rose to the position of vice-president and then to that of president. His next change was to that of president of Hare's Motors of New England and of Hare's Motors of Connecticut.

During the war years 1915 to 1916 Mr. Gilmore was in charge of maintenance and repairs on all airplanes and engines at Mineola Field, Long Island, for the First Aero Company of the National Guard of New York and the First Reserve Aero Company of the United States Army.

In November, 1920, Mr. Gilmore was elected Associate Member of the Society and later became active in the affairs of the New England Section, of which he was also a member.

Thomas G. Meachem

THOMAS G. MEACHEM, for a number of years vice-president and general manager of the New Process Gear Corp., of Syracuse, N. Y., and a pioneer in the development of gears for the automotive industry, died on Aug. 17 at the Mount Sinai Hospital, in New York City, following an operation. He had been in ill health for about three months.

Born at Onondaga Valley, N. Y., in 1878, Mr. Meachem attended Syracuse High School and St. John's Military Academy. In 1900 he became identified with the New Process Rawhide Co., founded by his father in 1888, which was engaged in cutting rawhide pinions and gears. The company later became the New Process Gear Corp. and Mr. Meachem was connected with it until 1918, during the greater part of this period as vice-president and general manager. In the automotive field the company first made driving gears for early electric vehicles, but later produced an entire line of timing, transmission, differential and other gears for motor-vehicles. The business was taken over by the Willys Corp. in 1918 and Mr. Meachem retired from the company. The following year, with his brother, he founded the Meachem Gear Corp., of which he was president. When the business was sold to other interests a few years ago, Mr. Meachem retired from active business, but continued to devote his time to other financial and civic enterprises at Syracuse.

Mr. Meachem was elected to Associate Membership in the Society in November, 1912, and was a member of the Buffalo Section.

Applicants for Membership

The applications for membership received between July 15 and Aug. 15, 1928, are listed below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

BERRY, JOHN HATTON, production manager, General Motors Export Co., *New York City*.

BISHONDEN, FRANK, engineer in charge of works, Metropolitan Motors, *Brisbane, Queensland, Australia*.

BLANCHAUD, L. H., consulting engineer, Bohn Aluminum & Brass Corp, *Detroit*.

BLASINGHAM, H. E., assistant general manager, Indiana Truck Corp., *Marion, Ind.*

BURGOINE, ALFRED CHARLES, assistant to chief engineer on production, Bristol Aeroplane Co., Ltd., *Bristol, England*.

CLARKSON, GEORGE WILSON, technical service representative, General Motors Products of Canada, *Winnipeg, Canada*.

COCHRAN, RALF S., metallurgical engineer, Surface Combustion Co., *Toledo, Ohio*.

COLLINS, ROBERT J., transportation engineer, Kansas City Power & Light Co., *Kansas City, Mo.*

CURTISS, ROBERT HENRY, mechanical superintendent, The Robert Simpson Co., Ltd., *Toronto, Canada*.

DOBBINS, ROBERT N., field mechanic, Gates Flying Circus, *Lodi, N. J.*

DOUGLAS, E. M., engineering representative in production, Studebaker Corp., *South Bend, Ind.*

HAMILTON, JAMES G., chief engineer, Cincinnati Ball Crank Co., *Cincinnati, Ohio*.

HEADLEY, BRADFORD N., lieutenant, United States Army, Office of Quartermaster General, *Boyds, Md.*

HECKMAN, JOHN L., owner, Heckman Machine Works, *Chicago*.

HUTCHENS, EDWARD, president, Utility Mfg. Co., *Cudahy, Wis.*

KLING, NELSON G., draftsman, Stewart Motor Corp., *Buffalo*.

LATHRUP, DONALD EDWARD, specification engineer, Graham-Paige Motor Car Co., *Detroit*.

LEIVISKA, YRJO (GEORGE), mechanic, General Motors Truck Co., *Detroit*.

LEGGAT, JOHN W., chief draftsman, Oakland Motor Car Co., *Pontiac, Mich.*

MAHON, PATRICK A., automobile engineman, City of New York, Borough President of Manhattan, *New York City*.

MILES, (MISS) MINNIE B., senior engineering aid, War Department, Ordnance, *City of Washington*.

MORGAN, LAWRENCE A., service man, The Buda Co., *Harvey, Ill.*

NEVIN, WILLIAM M., secretary-treasurer, Nevin Bus Lines, *Brooklyn, N. Y.*

NICKLIN, MAURICE E., sales engineer, Waukesha Motor Co., *Waukesha, Wis.*

OAK, PHILIP T., research engineer, Standard Oil Co. of Indiana, *Whiting, Ind.*

PAUL, EUGENE, chief mechanic, Dycer Airport, *Los Angeles*.

PENNEBAKER, R. H., lubricating engineer, Standard Oil Co. of Louisiana, *New Orleans*.

REISNER, J. HENRY, assistant production superintendent, Kreider Reisner Aircraft Co., *Hagerstown, Md.*

SCOLES, MARIO, motor designer, Willys-Overland Co., *Toledo, Ohio*.

SMITH, LESLIE ARCHIE, detailer, Packard Motor Car Co., *Detroit*.

SOLENBERGER, DEAN M., president, Simplex Piston Ring Co. of America, Inc., *Cleveland*.

SPROWLS, G. M., manager, highway transportation department, Goodyear Tire & Rubber Co., *Akron, Ohio*.

THOMPSON, E. J., shop superintendent, Reeve Gartzmann, Inc., *Los Angeles*.

THONGER, JOHN ROBERT, experimental engineer, LeRoi Co., *Milwaukee, Wis.*

TILSHER, GEORGE A., production engineer, Wright Aeronautical Corp., *Paterson, N. J.*

TREPTOW, HERMAN, service manager, Packard Motor Sales Corp., *New Brunswick, N. J.*

UILKEMA, T. J., designing engineer, Johnson Motor Co., *Waukegan, Ill.*

WAITE, GORDON T., chief aeronautical engineer, Alliance Aircraft Corp., *Alliance, Ohio*.

WALDNER, ERNEST, designer, Oakland Motor Car Co., *Pontiac, Mich.*

WALLACE, HIRAM LEW, research and tractor testing engineer, agricultural engineering dept., University of Nebraska, *Lincoln, Neb.*

WARNER, TOM HENRY, service manager, Long Mfg. Co., *Detroit*.

WEST, ROLAND A., teacher, Board of education, *Chicago*.

WHITE, CURTIS E., sales engineer, Penberthy Injector Co., *Detroit*.

WULF, RAYMOND H., president and treasurer., American Tube Bending Co., *New Haven, Conn.*

Applicants Qualified

The following applicants have qualified for admission to the Society between July 10 and Aug. 4, 1928. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff.) Affiliate; (S M) Service Member; (F M) Foreign Member.

ACKLIN, WILLIAM C. (A) secretary, treasurer, Acklin Stamping Co., *Toledo;* (mail) 1925 Nebraska Avenue.

BALCHEN, BERNT (M) pilot, Byrd Antarctic Expedition, New York City; (mail) 35 93rd Street, *Brooklyn, N. Y.*

BARFORD, VALENTINE GEORGE (F M) chief designer, J. I. Thornycroft & Co., Ltd., *Basingstoke, England;* (mail) 4 Wallis Road.

BARK, SYDNEY W. (M) chief inspector, Chrysler Corp., Highland Park Plant, Detroit; (mail) 615 West Troy Avenue, *Ferndale, Mich.*

BISBEE, D. P. (J) designer, Robert Thompson Co., Los Angeles; (mail) 210 West Orange Street, *Covina, Cal.*

BOYER, HAROLD B. (J) draftsman, American Car & Foundry Motors Co., *Detroit;* (mail) 356 Woodland Avenue.

BURK, FRANKLIN C. 2ND (J) assistant automotive research engineer, Vacuum Oil Co., Paulsboro, N. J.; (mail) 4545 Pulaski Avenue, *Philadelphia.*

CHAPIN, LAWRENCE W. (J) assistant to service manager, Twin Coach Co., Kent, Ohio; (mail) 1516 Arthur Avenue, *Lakewood, Ohio.*

CLARK, CHARLES S. (J) direct representative, State of Ohio, National Lock Washer Co., Newark, N. J.; (mail) 570 Rockefeller Building, *Cleveland.*

CONDIT, W. CHAPIN (J) student engineer, H. H. Franklin Mfg. Co., *Syracuse, N. Y.;* (mail) 123 Davis Street.

COX, RAYMOND J. (J) 210 Townsend Street, *New Brunswick, N. J.*

DAVISON, G. E. (A) research experimental work, Davison Engineering Corp., *Richmond, Va.;* (mail) 215 South Mulberry Street.

DEARTH, ELMER E. (M) manager product development, Fisk Rubber Co., *Chicopee Falls, Mass.*

DICKSON, V. F. (J) layout draftsman, Divco Detroit Corp., *Detroit;* (mail) 15431 Pinehurst Avenue.

DOUGALL, HECTOR FRASER (A) manager, proprietor, Dougall Motor Car Co., *Fort William, Canada.*

DYER, RAYMOND W. (M) standards department, Durant Motors, Inc., *Elizabeth, N. J.;* (mail) 34 Sayre Street.

FEHR, ROY B. (M) director of laboratory, Copland Gear Lapping Syndicate, 79 West Bethune Street, *Detroit.*

FENN, ALAN REGINALD (F M) managing director's assistant, Humber, Ltd., *Coventry, England.*

FRAZER, J. W. (A) sales manager, Chrysler Sales Corp., *Detroit;* (mail) 341 Massachusetts Avenue.

FRENCH, M. C. (M) lubricating sales engineer, Union Oil Co. of California, 604 Union Oil Building, *Los Angeles.*

FRIEDRICH, VILEM JIRI (F M) Spartan Aircraft Co., *Tulsa, Okla.*

GANDAIS, MARIS (J) draftsman, American Car & Foundry Motors Co., 5718 Russell Street, *Detroit.*

GIBIAN, EMIL (M) chief engineer, Velchek Tool Co., 3001 East 87th Street, *Cleveland.*

GUTTERSEN, ERNEST L. (J) vice-president, Willhelm Oil Co., 2361 Hampden Avenue, *St. Paul, Minn.*

HAMMOND, CHESTER ARTHUR (M) service engineer, New Departure Mfg. Co., Bristol, Conn.; (mail) Room 10-104, General Motors Building, *Detroit.*

HECTOR, EDWARD G. (J) junior engineer, tool designer, Houde Engineering Corp., *Buffalo;* (mail) 28 Verplanck Street.

HEBERT, FRED C. (M) layout engineer, wheel division, Budd Wheel Co., Detroit; (mail) 73 Tennyson Avenue, *Highland Park, Mich.*

HILL, JOHN B. (A) sales engineer, New Departure Mfg. Co., Room 10-111, General Motors Building, *Detroit.*

HODGE, ERNEST W. (A) superintendent of paint, Hudson Motor Car Co., *Detroit.*

HOPKINS, HOWE H. (J) draftsman, Nash Engineering Co., *South Norwalk, Conn.;* (mail) 4 Courtlandt Place.

HUMBLE OIL & REFINING CO. (Aff.) *Houston, Texas.* Representative: Monroe, M. J., sales manager.

JENSEN, OTTO H. (M) research engineer, Bossert Corp., *Utica, N. Y.*

JORGENSON, L. W. (A) shop superintendent, Motor Coach Co., Lomita, Cal.; (mail) 1619 Webster Street, *Alameda, Cal.*

KAMPE, J. LOUIS (A) sales engineer, L. A. Young Spring & Wire Corp., *Detroit;* (mail) 2682 Taylor Avenue.

KAW, H. (J) 70 Portage Park, *Highland Park, Mich.*

KING, HAROLD A. (A) manager, manufacturers' sales department, Seiberling Rubber Co., Akron, Ohio; (mail) 515 Coe Terminal Warehouse, West Fort and 10th Streets, *Detroit.*

KLINE, JOHN H. (A) local sales manager, International Harvester Co. of America, 44th Road at Vernon Boulevard, *Long Island City, N. Y.*

KREUTZER, JOSEPH (A) president, general manager, Joseph Kreutzer, Inc., 1801 South Hope Street, *Los Angeles.*

LAMBERT, ARTHUR J. (M) service manager, Garford Motor Truck Co., Inc., Long Island City, N. Y.; (mail) 117 South First Avenue, *Mount Vernon, N. Y.*

McFADDEN, THOMAS JAMES WALTER (A) district manager, Celoron Co., Bridgeport, Pa.; (mail) 425 Insurance Exchange Building, *Detroit.*

McFARLAND, FOREST REES (J) draftsman, Packard Motor Car Co., *Detroit;* (mail) 6927 Warren Avenue, East.

McSHANE, CARROLL A. (M) general service manager, secretary, treasurer, Jordan Philadelphia Service, Inc., Corner 16th and Melon Streets, *Philadelphia.*

MEEHAN, EDWIN J. (J) experimental, research, Divco Detroit Corp., Detroit; (mail) 1571 Cleophus Street, *Lincoln Park, Mich.*

MENTON, JOSEPH B. (M) body designer, Murray Corp. of America, *Detroit;* (mail) 15824 Normandy Avenue.

MILLER, HERMAN H. (A) supervisor of time study, Chrysler Corp., Avenue I, *Newcastle, Ind.*

MILLER, L. EARL (A) president, E. Earl Miller, Inc., 14 North 4th Avenue, *Mount Vernon, N. Y.*

MORTON, W. D. (A) manager, contest department, Auburn Automobile Co., *Auburn, Ind.*

OLTMANNS, A. M. (M) engineer, service division, Vacuum Oil Co., New York City; (mail) 801 70th Street, *Brooklyn, N. Y.*

PATON, ANDREW H. (J) draftsman, Chevrolet Motor Co., gear and axle division, *Detroit;* (mail) 1832 Pilgrim Avenue.

PODVIN, A. F. (A) general sales manager, Northwestern Oil Co., *Superior, Wis.*

POST, GEORGE B. (M) president, Free Bottom Craft, Inc.; New York representative, Keystone Aircraft Corp.; (mail) Free Bottom Craft, Inc., 475 Fifth Avenue, *New York City.*

REID, W. T. (M) president, Reid Aircraft Co., Ltd., 120 St. James Street, *Montreal, Que., Canada.*

RICHARDS, THOMAS ORIN (J) head, technical data section, General Motors Research Laboratories, General Motors Building, *Detroit.*

RICKENBACKER, EDWARD V. (M) assistant general sales manager, charge of La Salle division, Cadillac Motor Car Co., 2860 Clark Avenue, *Detroit.*

RODE, FRED J. (M) factory manager, chief engineer, Marquette Tool & Mfg. Co., 1900 North Kilbourn Street, *Chicago.*

ROUX, ROBERT (A) Walter Motor Truck Co., Long Island City, N. Y.; (mail) 1649 St. Nicholas Avenue, Apartment 7c, *New York City.*

ROWLEY, MILLARD C. (J) engineer, Lycoming Mfg. Co., *Williamsport, Pa.;* (mail) 1036 West Fourth Street.

SAXON, DAVID L. (A) vice-president, Saxon Stamping Co., 122 Southard Avenue, *Toledo.*

SMITH, EDWIN R. (A) vice-president, general manager, Seneca Falls Machine Co., *Seneca Falls, N. Y.*

SMITH, MARK H. (J) layout draftsman, Ford Motor Co., Dearborn, Mich.; (mail) 2714 Clairmount Avenue, *Detroit.*

STECKLER, AUGUST G. (A) factory operating engineer, Checker Cab Mfg. Corp., Kalamazoo, Mich.; (mail) Care of Standard Cab Co., 615 St. James Street, *Montreal, Que., Canada.*

SUMNER, FRED (F M) draftsman, designer, Morris Commercial Cars, Ltd., Birmingham, England; (mail) Loganhurst, 85 St. Albans Road, *St. Annes-on-Sea, Lancashire, England.*

TAFT, BURTON M. (A) vice-president, manager, Reo Michigan Sales, Inc., 2272 Jefferson Avenue, *Detroit.*

TAYLOR, HAROLD M. (A) district manager, Firestone Tire & Rubber Co., 4264 Woodward Avenue, *Detroit.*

VAUGHN, CLARENCE K., JR. (J) service manager, Leavenworth Motor Co., *Leavenworth, Kan.;* (mail) 767 Miami Street.

WILLENBUCHER, EUGENE HENRY (A) automotive engineer, lubricating bus lines and truck fleets, The Texas Co., *Norfolk, Va.;* (mail) P. O. Drawer 1115.

WINKLER, HERMAN E. (J) engineer, Schwitzer-Cummins Co., *Indianapolis;* (mail) 2521 Ashland Avenue.

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Notes and Reviews

These items, which are prepared by the Research Department, give brief descriptions of technical books and articles on automotive subjects. As a general rule, no attempt is made to give an exhaustive review, the purpose being to indicate what of special interest to the automotive industry has been published.

The letters and numbers in brackets following the titles classify the articles into the following divisions and subdivisions: *Divisions*—A, Aircraft; B, Body; C, Chassis Parts; D, Education; E, Engines; F, Highways; G, Material; H, Miscellaneous; I, Motorboat; J, Motorcoach; K, Motor-Truck; L, Passenger Car; M, Tractor. *Subdivisions*—1, Design and Research; 2, Maintenance and Service; 3, Miscellaneous; 4, Operation; 5, Production; 6, Sales.

AIRCRAFT

Raketenversuche mit Flugzeugen und Flugzeugmodellen. By A. Lippisch and F. Stamer. Published in *Zeitschrift für Flugtechnik und Motorluftschiffahrt*, June 28, 1928, p. 270. [A-1]

The much-talked-of rocket-propulsion of airplanes is here dealt with by two investigators who participated in the research. One contributes technical notes; the other, an account of flights made in the course of the experiments, which embraced both model and full-size airplanes.

The verdict arrived at, so far as this preliminary research justifies the formation of an opinion, is that rocket-propulsion of airplanes is thoroughly feasible. The practical trials have led the authors to a keen realization of the necessity of taking every precaution against the firing of the aircraft by the rockets. A number of suggested safeguards are mentioned.

The Drag of a J-5 Radial Air-Cooled Engine. By Fred E. Weick. National Advisory Committee for Aeronautics Technical Note No. 292. Published by National Advisory Committee for Aeronautics, City of Washington. 4 pp.; 5 illustrations. [A-1]

The drag due to radial air-cooled engines is a subject of considerable interest at this time. This note describes tests of the drag caused by a Wright Whirlwind J-5 radial air-cooled engine mounted on a cabin-type airplane. The tests were made in a 20-ft. propeller-research tunnel.

Three different types of exhaust stack were used in the investigation: short individual stacks, a circular cross-section collector ring, and a streamline cross-section collector ring. The drag due to the engine was found to be 85 lb. at 100 m.p.h. with the individual stacks and 83 lb. at 100 m.p.h. with each of the collector rings.

The ABC of Flight. By W. Laurence LePage. Published by John Wiley & Sons, New York City. 141 pp.; 42 illustrations. [A-3]

The history of an art might well be traced by the character of books written concerning it. Were there any doubt that aviation has become a thing of the people, it would be dispelled by the increasing number and the excellence of the books written about it for the layman. These avoid the abstruse and involved reasoning of the scientist, on the one hand, and, on the other, the concrete bread-and-butter details of the mechanic; they touch on the realm of theory by lucid interpretations of the general principles of flight, and on the practical by revelations of the ingenious devices that have been evolved to utilize these principles.

The latest of these books, The ABC of Flight, represents high quality and a distinct advance in the stage of popularization it attributes to aviation. Its author, W. Laurence LePage, has the ability to instruct conferred by many years of intimate association with his subject. He has had extended experience in aeronautical research engineering and has long been identified with the literature of aviation. He assumes that the general reader is interested, not only in the theory of aviation, but in the processes of manufacture and in the actual business of learning to fly. In tone his book looks forward to the time when the man on the street will refer to his plane as nonchalantly as he now speaks of his car.

Ground Transport for an Air Organization. By R. E. H. Allen. Published in *The Journal of the Royal Aeronautical Society*, July, 1928, p. 596. [A-4]

A self-contained organization for maintaining an air fleet needs many more types of ground vehicle than of aircraft. This is the author's thesis, which he demonstrates in a paper characterized by one of its discussers as a liberal education in the design of specialized bodies.

In the Royal Air Force organization, the equipment of which is the basis of this paper, existing commercial chassis meet all requirements for prime movers and for the ordinary transport of goods and passengers. Fourteen different types of special technical vehicle are used in the operation, repair, and defense of aircraft and are here described, as well as certain miscellaneous ground equipment.

Some of the lines of development discerned by the author are: the discarding of solid for pneumatic tires; increasing utilization of trailers; lighter chassis more scientifically designed to withstand rough usage; a leaning toward the cross-country vehicle; cylinder-heads which, by improved turbulence, make possible the use of a lower-grade fuel; the development of easier gear-changing; the use of less robust chassis that are cheaper in first cost and maintenance, rather than expensive chassis of long life; and the providing of greater comfort for drivers and crew.

Airport Runway and Surface Treatments. By N. H. Angell. Published in *Aviation*, July 16, 1928, p. 176. [A-4]

This article, which treats a subject almost wholly neglected in the technical literature and only slightly more regarded in practice, has a special appeal. The importance of suitable surfacing for airport fields and runways is equaled by the difficulty of meeting the requirements. Such surface must be smooth, true to grade, as resilient as possible, free from gravel, and of good visibility, to mention a few measures of its efficiency.

After referring to a few of the runways from which recent long-distance flights were launched, the author describes some types of surface used and comments on their utility from different angles. The deduction made from present developments is that surfaces of either the asphaltic-concrete or oiled-earth type will be considered with special favor in future airport construction.

Fast-Growing Air Traffic Brings Need for Quick Fueling Methods. By Roger B. Stafford. Published in *National Petroleum News*, July 11, 1928, p. 17. [A-4]

Oil and equipment companies that are awake to the needs of the hour are developing means of refueling airplanes, to bring to an end the anomaly of a means of transportation designed essentially for speed being delayed for three or four hours to take aboard its gasoline supply.

Descriptions are given of the equipment installed at the Ford airports at Dearborn and Cleveland, the Heil mobile service-unit at Buffalo, and the Bowser stationary set-up.

Gluing Practice at Aircraft Manufacturing Plants and Repair Stations. By T. R. Truax. National Advisory Committee for Aeronautics Technical Note No. 291. Published by the National Advisory Committee for Aeronautics, City of Washington. 11 pp.; 1 illustration. [A-4]

Gluing practice in the aircraft industry does not compare favorably in general with gluing practice in certain

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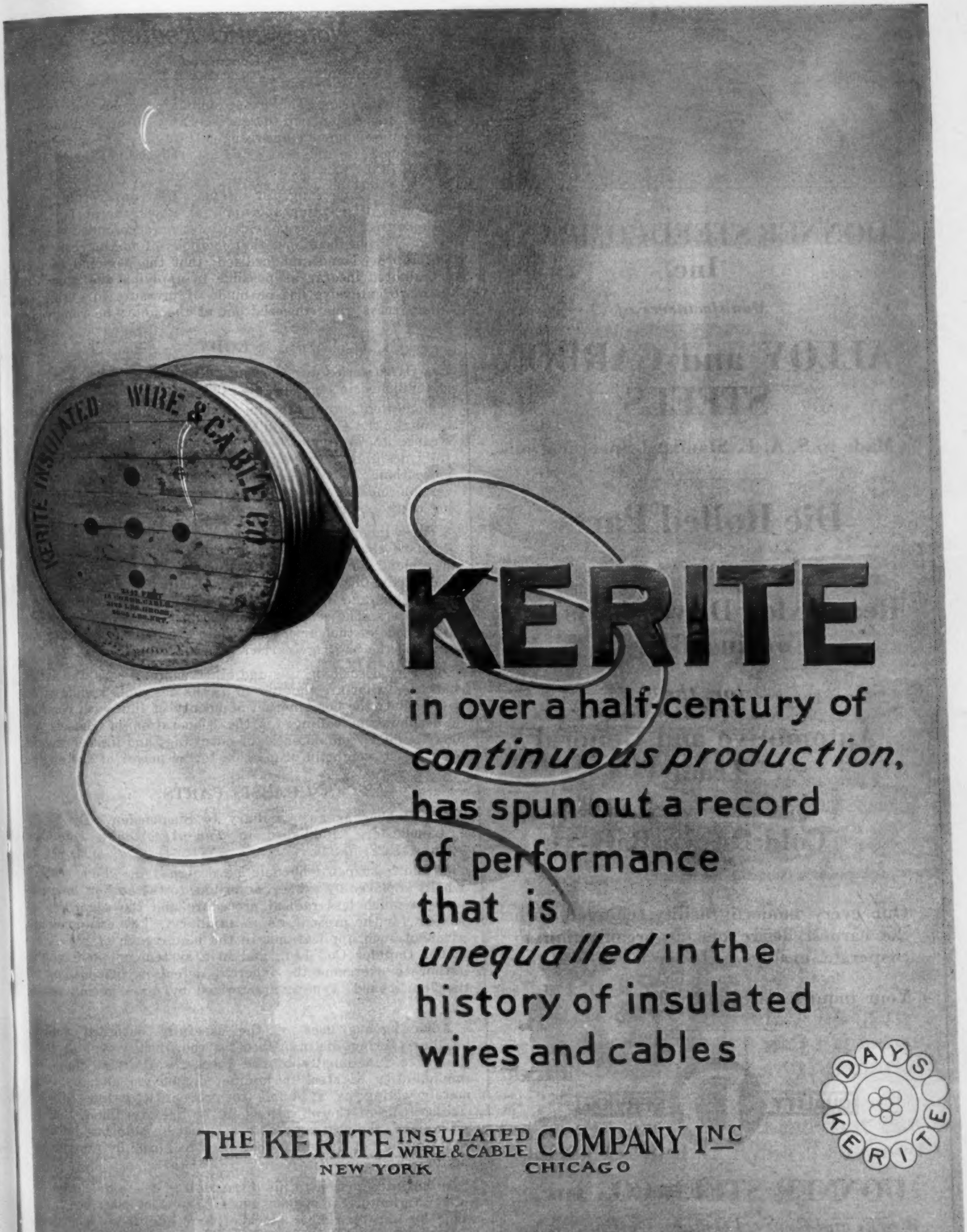
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Notes and Reviews

Continued

other industries. This is the summary of observations made on an inspection trip to representative aircraft manufacturing establishments and repair stations. The investigation was made for the Navy and covered the period from Nov. 23, 1926, to Feb. 16, 1927.

After commenting, for the most part unfavorably, on the methods of selecting and applying glues, the author recommends that all glues be tested in strict accordance with Government specifications; that methods of mixing casein glue be improved and standardized; that the personal factor be eliminated insofar as possible in applying the glues; that a more extensive use be made of pressure in gluing; and that excess glue squeezed out at the joints be removed.

BODY

Les Carrosseries au "Concours d'Elégance." By A. Caputo. Published in *Omnia*, July, 1928, p. 92. [B-1]

Somewhat similar in aim to the Automobile Salon of this Country, the Concours d'Élégance has established itself in France as an annual demonstration of elaborate and carefully designed body-work. This year's assembly embraced more than 250 vehicles, for the most part closed and convertible models, the comparatively few open-car entries being of the sport type.

The winner of the first prize, a sedan on a sleeve-valve Panhard chassis, is stated by the author to satisfy the requirements for an ideal body for French usage. It is light and silent, its use makes possible both economy and speed in running, and it has every provision for the comfort of the passengers. The seats are convertible into beds, receptacles at the side of the car accommodate extensive picnicking outfits, and the baggage carriers are ample.

Besides describing this and other winning cars, the article indicates what are thought to be the desirable trends of development: the combination of beauty of line with comfort, a desideratum calling for the cooperation of chassis and body builder; completeness of outfitting; and lighter weight, or at least weight in proportion to the power of the engine.

CHASSIS PARTS

India Rubber as an Auxiliary to Suspension. By F. W. Lanchester. Published in *The Automobile Engineer*, June, 1928, p. 226. [C-1]

While a suspension could be designed in which steel is wholly replaced by rubber, according to the author, he advocates a much less radical procedure and the regarding of rubber, for the present, as an auxiliary. Two examples are given of such applications, in the motorcoach of the Associated Daimler Co., Ltd., and in a system adopted by the author to overcome the inherent defect in suspensions of the "buckboard" type characterized by quick-period pitching.

Advantageous uses of the carefully designed rubber auxiliary-spring distinguished by the author are: to take the place functionally of the shock-absorber; to diminish the quantity of steel in laminated springs, and, by ultimately acting as a buffer, to prevent excessive spring-stress. One of the objections to the use of rubber, that it is likely to take a permanent set, is met by pointing out that no large part of the static load need be borne by the rubber auxiliary.

As an introduction to his discussion of the application of rubber to motor-car suspensions, the author describes tests made by him on rubber stock of four qualities. The purposes of these tests were to determine the modulus of elasticity and the energy coefficient of restitution of the specimens; and they included bouncing or dropped-ball, oscillating beam, and testing-machine tests.

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Notes and Reviews

Continued

The Automobile Drive-Shaft. By Raymond L. Rolf. Published in *Transactions of the American Society for Steel Treating*, July, 1928, p. 72. [C-1]

This paper outlines briefly in a non-technical way the manufacture of the automobile drive-shaft, touching upon such features as design, forging, machining, testing, physical properties and materials used. It deals also with the advantage of using a molybdenum steel to obtain easy machinability at high Brinell hardnesses, thus enabling shafts to be completely machined in the heat-treated state.

Testing of Motor-Vehicle Headlighting Devices and Investigation of Certain Phases of the Headlight Glare Problem. By C. R. Granberry. University of Texas Bulletin No. 2831. Published by the University of Texas, Austin, Texas. 34 pp.; 16 illustrations. [C-1]

This bulletin is issued by the Bureau of Engineering Research of the University of Texas to show the nature of the routine and research work carried on in the photometric laboratory of the institution. During the last two years most of the routine work has been that of testing various types of automobile headlight equipment for the Texas State Highway Department. The results of these tests and certain discussion regarding the general question of automobile headlighting progress are included in this pamphlet.

The first project of the research work described was designed to determine the effect on vision of headlight brightness and background contrast, with the time factor reduced to unimportance as far as approximating actual driving conditions is concerned. The second investigation included the factors of brightness and background contrast and, in addition, one phase of the time element.

The experiments were conducted in the laboratory with a 26-sq. ft. area, representing the road, placed just to the side of an automobile head-lamp which consisted of a bulb in a bare reflector. A large dome reflector was suspended above the road so as to give a sufficiently uniform illumination over the entire area. The headlight beam was aimed directly at the observer. The road surfaces used were black dirt, red gravel and crushed limestone.

ENGINES

Le Moteur Diesel Léger Peugeot. By Marc Chauvierre. Published in *La Vie Automobile*, June 25, 1928, p. 241. [E-1]

The only novelty noted by the author of this article at the 1928 showing of commercial vehicles in Paris was a Peugeot truck powered by a light Diesel engine. The uniqueness of the engine did not consist in the embodiment of any new features, as it was of the ordinary Junkers two-stroke-cycle air-injection type, with two opposing pistons operating in one cylinder. The accomplishment of the Peugeot powerplant that merits special acclaim, in the opinion of the author, is the overcoming of two of the usual obstacles to the automotive use of Diesel engines, as it is both light in weight and easy to start.

The description of the design and operation of the engine shows how these two advantages are secured.

The Coal-Dust Engine Upsets Traditions. By R. Pavolikowski. Published in *Power*, July 24, 1928, p. 136. [E-1]

After 15 years of development and 12 years of practical operation, a vertical 16½ x 25-in. single-cylinder four-stroke-cycle engine burning coal directly in the cylinder has demonstrated the feasibility of this type of fuel usage, in the opinion of the author.

One advantage claimed for the pulverized coal engine as compared with the Diesel engine is that it compresses the fuel and combustion-air simultaneously, but keeps them

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separated until ignition occurs. In the Diesel engine, on the other hand, the incoming fuel-oil must be heated and ignited in the extremely short period afforded by the fraction of a single stroke. Economy is also claimed, since in Germany 1 b.hp-hr. can be delivered at a cost of $0.12 with pulverized coal, whereas the cost with oil would be about $0.45. The criticism of rapid wear directed against this type of engine is said to have been groved groundless.

The design, operation and development of the engine are described.

Connecting-Rods. By C. B. Dicksee. Published in *The Automobile Engineer*, June, 1928, p. 208. [E-1]

For a connecting-rod to be uniformly strong in each direction, the author points out, its moment of inertia measured in the plane of rotation should be four times as great as that measured in the plane of the crankshaft.

This requirement can be satisfied by a number of different cross-sections, the article continues. The H-section commonly adopted for automobile and aircraft engines may be made in widely different proportions and still fulfill the condition. Accurate determination of the correct cross-section is a tedious process, and recourse generally is had to the use for all occasions of a set of proportions known to give the values in the correct relationship.

The purpose of this article is to show that a fixed set of proportions is applicable to a given set of circumstances only, and also to give a method by which a more correct and economical section can be arrived at without trouble. An example is given to illustrate the procedure, and a few remarks are made on the effects of using materials of different characteristics.

Shaft Speeds. By J. Morris. Published in *The Automobile Engineer*, June, 1928, p. 217. [E-1]

Assuming that, in a shaft design, suitable steps are taken to avoid a resonant speed within the running range, the next question that presents itself is, Should the running speed be above or below a critical speed and by what amount?

An effort is made in this article to investigate the problem analytically, to produce data that may assist in its solution, and to determine the lightest shaft that will withstand the stresses involved in running.

The deduction drawn from the analysis is that, if a series of shafts of the same length but of varying radii are all subject to a torque compounded of two parts, one constant and the other periodic, one particular shaft will be subject, at a given speed which governs the periodicity of the torque, to infinite stress at that speed; that, of shafts whose radii are less than that of this particular shaft of radius r_0 for instance, that shaft will be least stressed whose radius is $r = 0.85\ r_0$; and that, of shafts whose radii are greater than r_0, those for which $r > 1.11\ r_0$ will be less stressed than those whose radii are below this value.

Storage Batteries. By Morton Arendt. Published by D. Van Nostrand Co., Inc., New York City. 285 pp:; 156 illustrations. [E-3]

The practical electrical engineer is appealed to in this book, which is a development of the author's lectures to engineering students at Columbia University and to officers at the Submarine School of the Navy during a period of years. It is also based on his experience in battery manufacture and maintenance.

Such material as can be applied readily to every-day problems relating to the manufacture and assembling of storage batteries, to questions having to do with their upkeep and care, and to their application and usage comprise the scope of this treatise. Pure theory has been subordinated to the requirements of practice, only that theory

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which explains in a general way storage-battery chemistry and cell characteristics being taken up. In connection with the latter, the author studies plate construction and the diffusion of electrolytes as controlling factors.

No less than 18 specific major uses are listed and explained in the last chapter, which deals with storage-battery applications. In this connection, it is interesting to note that, although the storage battery is relatively an old device, its manufacture has become an important industry only within the last 15 years. This growth, represented by an increase in the value of total sales from $12,000,000 to $100,000,000 a year from 1914 to 1924 and an increase in the quantity of plate material used yearly from 40,000,000 to 200,000,000 lb. over the same period, is traced to the introduction of automobile lighting and starting equipment and the wide use of radio receiving sets.

MATERIAL

The Geology of Petroleum and Natural Gas. By Ernest Raymond Lilley. Published by D. Van Nostrand Co., Inc., New York City. 523 pp.; 173 illustrations. [G-1]

The story of oil is here told as it may be read from the composition of the material itself and from the rock and sand formations that attend its occurrence. Upon the mute evidence of centuries of cosmic activity, theories are built as to the origin of the precious liquid and its course through the earth until it is found by man. Deductive reasoning is then applied to develop the scientific principles on which should be based the search for new producing areas.

Scholarly in its careful accumulation, examination and orderly arrangement of data, the book will be readily intelligible to the reader not versed in this particular branch of science, because of the clarity of its language and its avoidance of abstruse technicalities.

It will find lay readers of two types: the one interested, from a scientific viewpoint, in the origin of substances, and the practical man bent on knowing how they may be profitably discovered and utilized.

For the petroleum geologist it will prove a handy reference book, as it embodies brief statements of the principles of the science and examples illustrative of their application. It is a well-coordinated summary of the large mass of data that, because of the great activity of the oil industry, has been collected in the last 70 years.

Applied Elasticity. By S. Timoshenko and J. M. Lessells. Published by Westinghouse Technical Night School Press, East Pittsburgh, Pa. 544 pp.; 391 illustrations. [G-1]

Two engine problems that are receiving attention in automobile and aeronautic engines at present are those of vibration and of weight reduction. So much material bearing on these two subjects is contained in the book Applied Elasticity that it merits mention as an important, if not a new, contribution to their study.

The first section of the book is analytical, containing some advanced chapters devoted to the theory of the strength of materials. Some solutions based on the mathematical theory of elasticity are also presented for those cases of stress distribution in which elementary methods cannot give satisfactory results. An entire chapter in this section is devoted to problems on dynamical stresses produced in moving machine-parts by inertia and vibrations. After a review of the general theory of vibration of elastic systems, several practical problems are discussed, such as critical speeds of shafts, torsional vibrations of shafts, and stresses produced during impact.

The second section contains information on the mechanical properties of materials, principally metals, used in modern construction. The great variety of special materials now employed can be intelligently applied only after a careful study of the characteristics of each, the demand for

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Art Bumpers by C.G.
1929
Wm Meyerhuber
CG
chromium plated
BUMPERS
© 1928, THE C. G. SPRING AND BUMPER COMPANY, DETROIT. [911]

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weight economy making this study all the more imperative. For this reason the chapters on the experimental testing of metals have distinct value, especially the final culmination, the chapter on working-stresses. In this the numerical data obtained for commonly used and special steels are presented so that they can be used immediately. Various methods of proportioning the limiting stress-values in design are also given.

Properties of Materials at High Temperatures; No. 3, Note on the Creep of Armco Iron. By H. J. Tapsell. Department of Scientific and Industrial Research, Engineering Research Special Report No. 6. Published by the Department of Scientific and Industrial Research, London, England. 11 pp.; 2 illustrations. [G-1]

Experiments described in this report were made with the object of gaining further knowledge of the creep characteristics of metals at high temperatures, Armco being used as a metal peculiarly susceptible to this phenomenon. More specifically, they were undertaken with a view to illustrating clearly the incidence of a hardening effect observed during previous experiments, and to show that, at any rate within the range of temperatures investigated, 302 to 734 deg. fahr., both strain-hardening and temperature-hardening of Armco iron occur during creep, and that at temperatures below the limiting creep-values, continued stress appears to be accompanied by a decrease of plasticity, resulting in the final attainment of perfect elasticity up to the stress applied.

Bearing Metals. By E. C. Wadlow. Published in *The Automobile Engineer*, June, 1928, p. 221. [G-1]

The author puts the investigation here described in the category of practical research, dealing with commercial materials and attempting to supply data of direct value to the designer, as distinguished from the purely scientific man concerned with fundamentals and employing ideal conditions.

Arising out of an inquiry as to the suitability of cold-drawn and extruded tubes for plain-journal bearings, the investigation embraced 14 different bearing materials, among them the following: tin and lead-base white metal, cast phosphor-bronze, cold-drawn phosphor-bronze tube, sand-cast lead-bronze, chill-cast gun-metal and phosphor-bronze, annealed phosphor-bronze, extruded brass tube, sand-cast zinc-bronze, and aluminum-zinc alloy. The performance of the material under test was gaged by using it as the bearing in a machine modified for the purpose.

Among the facts thought to have been demonstrated by the investigation are the superiority of the tin-base white metal, the detrimental effect of zinc, the unsatisfactory performance of most of the materials tested, and the lack of relationship between the Brinell hardness-numbers or microstructures and figures of merit. The cold-drawn phosphor-bronze tubing, the worth of which was the main interest of the research, was found to be not very satisfactory. For light work, the author concedes, it will probably give good results, but where conditions are onerous the use of tin-base white metals or suitably cast phosphor-bronze is advisable.

Mineral Resources of the United States in 1925: Part 1, Metals; Part 2, Non-Metals. By Frank J. Katz. Published by Bureau of Mines, City of Washington. 768 pp.; 615 pp. [G-3]

The accumulation of statistics for 1925 on the production in the United States, and the imports and exports, of minerals makes these two volumes of value for reference. Some information on the uses of the various materials is also included, as well as figures indicating the extent of foreign sources, where these are considerable.

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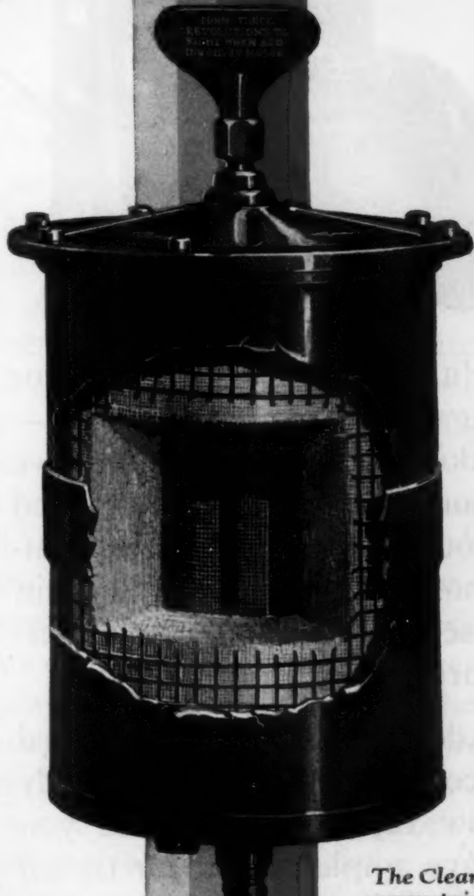

The Clearifier is built on a new principle. Inside is a filter cartridge of special filter cloth in the form of a roll with a hollow center, forming a chamber into which the used oil flows. A twist of the knob when oil is renewed reels up the innermost winding facing this chamber, removing the dirt-laden filter area from contact with the oil and exposing fresh surface. The Clearifier is 8" high over all by 5¼" in diameter, and weighs 2 lb. 15 oz.

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TRAFFIC-TESTED PRODUCTS

Notes and Reviews

Continued

As is shown by statistics assembled in this report, the total value of mineral products of the United States in 1925 was $5,677,630,000. The total value of metallic products, of which 30 are listed in Part 1, was $1,380,380,000. Non-metallic minerals, excluding fuels, of which slightly more than 30 are covered in Part 2, were produced to a value of $1,232,420,000; while the output of the four fuels—coal, petroleum, natural gas and natural-gas gasoline—had an aggregate worth of $3,058,680,000.

Two of the general comments made on the statistics are of particular interest. The movement in the refining industry is said to be toward greater efficiency of operation, either by consolidation or improved methods. In the second place, the imports of chromium for 1925 were the second largest in the history of this industry, part of the increased consumption being attributed to the greater utilization of stainless steel and non-corrosive alloys.

MISCELLANEOUS

Mechanics for Engineers. By Julian C. Smallwood and Frank W. Kouwenhoven. Published by D. Van Nostrand Co., Inc., New York City. 185 pp.; 204 illustrations. [H-3]

In contributing this book to the flood of available literature on the subject, the authors claim nothing new except an arrangement and a selection of material, a combination of problems with text for the exercise of the best pedagogy, and an emphasis upon subjects important to engineering students, with corresponding omission or reduction of less important ones.

The material is arranged so that the easier problems come first, with only enough definitions presented to cover that part. Notions of velocity and acceleration in pure rectilinear and rotative motion and the relations between them are given just before the topics of kinetics. Subjects such as the friction circle and the motion of projectiles are omitted because it is thought that the average engineering student, after graduation, has no use for them. Problems are interspersed through the text in such a way that the student cannot read very far before he meets an illustrative problem, followed by several others for him to solve. The physical interpretation of all the equations and laws presented is emphasized.

MOTORCOACH

City Transportation Expands on Rubber. By R. E. Plimpton. Published in *Bus Transportation*, July, 1928, p. 382. [J-4]

This article is unusually comprehensive, describing the motorcoach transportation systems in nine urban centers ranging from 25,000 to 500,000 population. The localities were selected because they were thought to be typical of the many cities in the under-half-million class that must depend largely on surface transportation for the daily or periodic movement of their inhabitants.

In each case an appreciable part of the public passenger transportation is being supplied by the motor carrier. Otherwise, conditions vary widely, one city having municipal ownership while another ignores the trend toward unification, one stringently restricting facilities to the minimum required for efficiency and another lavishly providing too much transportation, and so forth.

The information given was gathered by the author on personal visits to the nine cities. It includes data on the size and layout of the localities, the extent of motorcoach facilities, the earnings of the companies, and any outstanding peculiarities in operating methods or in conditions to be met.

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A Survey of Railway Motorcoach and Motor-Truck Operation. Published in *Railway Age*, June 23, 1928, Pt. 2, p. 1468. [J-4]

Figures can best tell the story of the expansion of the use of motor-vehicles by the steam railroads. The significant statistics for motorcoach operation are:

	1928	1927
Number of roads operating motorcoaches	64	52
Number of motorcoaches operated	1,047	800
Number of motorcoach routes operated	340	200
Aggregate motorcoach route mileage	14,805	8,000

Progress in railroad motor-truck operation is summarized as follows:

	1928	1927
Number of roads operating trucks, tractors and trailers	49	31
Number of trucks, tractors and trailers operated	4,902	3,300
Number of routes and terminals served	298	250
Aggregate motor-truck route mileage	3,521	....

These figures are the totals obtained in surveys conducted by *Railway Age*. The details for the census completed on June 1, 1928, published in this article, include the names of the railroads and their operating companies, the numbers of vehicles operated, total miles of line, routes operated and mileage of each, and the date of initiation of service.

PASSENGER-CAR

The Campbell-Napier Car. Published in *The Automobile Engineer*, June, 1928, p. 194. [L-1]

This car, specially built for the definite purpose of attaining a speed of 210 to 220 m.p.h., contains not a single standard component, aside from the engine ports. This descriptive article embodies a close examination of the design and production methods responsible for the evolution of a world speed-record winner. In the opinion of its designers the car is capable of rewinning its laurels from Ray Keech, who, after its first run, attained a higher speed.

Of the many interesting and original features of the layout, the epicyclic gear receives the most distinctive mention. Its main recommendation is the elimination of frictional braking surfaces for the purpose of obtaining the torque, the satellite carriers being brought to rest positively and the power transmitted without the least friction. The efficiency of the gear is said to be so high that, by a slight pressure of the thumb on the satellite wheel of the second-speed element when in gear against the resistance of the primary shaft coupled to the engine, the car can be made to crawl.

Auswertung der ADAC Gebrauchs und Wirtschaftlichkeitsprüfung 1928. By Slevogt. Published in *Der Motorwagen*, June 30, 1928, p. 401. [L-4]

For the sake of those interested in automobiling as a sport and of purchasers of motor-cars, the author says that tests should be made of the general performance and ability of the various makes of car on the market. The road trials of the General German Automobile Club, organized to fill this need, were opposed in German industrial circles but received the support of the Ministry of Transport.

According to the detailed account given in this article 32 cars were entered in the competition, the following makes being represented: Ford, Adler, Brennabor, Steyr, Dixi, Hanomag, Opel and Wanderer. The entries were divided into two, four and six-passenger classes. The performance features measured were starting ability of both the engine and the car as a whole; acceleration both in direct drive and through gears; the minimum and maximum speed

(Concluded on next left-hand page)

Notes and Reviews

Concluded

in direct drive; fuel consumption; hill-climbing ability, and steering. Efforts were also made to arrive at the general dependability and maneuverability, riding-qualities and wear resistance of the cars.

In the accumulated scores for all items, a Ford car was rated highest in the two-passenger group, with an Adler second; three Adlers took the first three places in the four-passenger group; three Brennabors duplicated this performance for the six-passenger division, with the Adler, the only other entry in this class, in fourth place.

Welding in the Ford Industries. By M. L. Eckman. Published in *Journal of the American Welding Society*, May, p. 31; June, 1928, p. 44. [L-5]

Welding is not only the world's best assembly method but is also the keystone on which rests the further development of the best manufacturing methods now in use. This is Henry Ford's attitude toward welding, as interpreted by the author, and it led Mr. Ford to turn his plant into a great welding laboratory, with results described in this article.

Electrical resistance flash-welding is used, and the part it plays in the production of the following assemblies is dealt with: rear axle, differential housing, differential ring-gear, hand-brake lever, muffler, wheel, battery support, steering-gear, fan, doors and frame, and fuel tank.

The Tractor Field-Book, with Power Farm-Equipment Specifications. Published by Farm Implement News Co., Chicago, 141 pp. [M-3]

This book, which assembles in one volume many miscellaneous facts, well fulfills its mission of being a compilation of value to those who make, sell or use equipment for power-farming.

Four sections are included. The first contains specifications of combines, husker-shredders, shellers, silo fillers, threshers, and tractors; and illustrated descriptions of the last-named are given. The second section includes such items as the results of Nebraska tractor tests for current models, tractor production and distribution, and sizes of various tractor replacement parts. Classified lists of parts manufacturers make up the third division; and in the fourth are articles giving directions for the operation and servicing of tractors.

Inspection Methods and Their Application. By Fred H. Colvin. Published in *American Machinist*, Aug. 2, 1928, p. 183. [M-5]

Growing away from the old attitude that the duty of the inspector is to reject as much work as possible, inspection departments generally are adopting the more modern view that their mission is so to cooperate with the production department as to secure the greatest number of pieces that will function properly in the completed mechanism.

This is the conclusion that may be drawn from the present article, which reviews the general theory of various methods of inspection and gives some specific examples of apparatus and procedure.

A large portion of the article deals with the practice of the Caterpillar Tractor Co. This company is said to inspect thoroughly and check important castings before sending them to the machine department. A test for possible leaks and a method of checking all the portions of a casting that have to be machined or that affect clearances of moving parts are described.

An example of the inspection of forgings found in the Caterpillar plant is also cited. This inspection method is used in connection with the side links in the track that forms the caterpillar-tread.

Personal Notes of the Members

(Continued from page 331)

Metal Body Co., in Ohio, is now body draftsman for Locke & Co. at Rochester, N. Y.

Roy F. Anderson has been promoted from the position of chief engineer of the Hayes Body Co., of Grand Rapids, Mich., to that of vice-president in charge of engineering for the same company.

Howard Brooks recently formed a connection as mechanical superintendent for the Charcas, Mexico, unit of the Cia Minera Asarco, of South America. He formerly acted as assistant superintendent of the American Smelters Securities Co., Velardena, Durango, Mexico.

Raymond J. Burgh, who recently completed his studies at Purdue University, has accepted the post of assistant in mechanical engineering in Brown University, Providence, R. I.

Ralph B. Burton, formerly a consulting engineer at Indianapolis, has established a connection with the Johnson Motor Co., of Waukegan, Ill.

Frederic Canali, previously a member of the engineering staff of the Hupp Motor Car Corp., Detroit, has joined the forces of the Checker Cab Mfg. Corp., Kalamazoo, Mich.

Dudley Chambers recently severed his connection with the American Cable Co. to become assistant chief engineer of the Universal Motor Co., Oshkosh, Wis.

Sih-van Chang recently entered the service of Dodge Brothers, Inc., Detroit, as a student. Prior to making this connection Mr. Chang was a student at Cornell University.

William C. Colton, Jr., has been promoted from the position of chief designer to that of general superintendent of the North American Watch Co., at Mansfield, Ohio.

Arthur R. Constantine, a former member of the engineering force of Harley-Davidson Motor Co., Milwaukee, recently accepted the position of chief engineer for the Excelsior Motor Mfg. & Supply Co. at Chicago.

S. J. Cooper recently left the Freed Motor Co., of Miami, Fla., where he was employed as service manager, to accept a similar position with the John H. Thompson Co. in Detroit.

H. S. Dale, student at Purdue University, has been employed by the Glenn L. Martin Co. at Cleveland in a designing capacity.

Shen how Fong, who has been studying at Cornell University, is now associated, in the capacity of surveyor and draftsman, with the Department of Public Works, Division of Highways, of the State of New York.

Frank Free has joined the Alexander Aircraft Co., Colorado Springs, Colo., as sales promotion manager. Mr. Free will also be engaged in engine experimental work.

G. O. Goller recently sailed for Europe to assume his new duties with the General Motors G.M.B.H. in Berlin-Borsigwalde, Germany. Mr. Goller was previously body engineer for the Fisher Body Corp.

J. Allen Good, a former student at the University of Nebraska, is now cadet engineer with the Bailey Meter Co., located at Cleveland.

V. F. Halliburton became purchasing agent on Aug. 1 for the Spartan Aircraft Co., of Tulsa, Okla. He was formerly assistant purchasing agent for the Mid-Continental Petroleum Corp., located in the same city.

D. S. Harder has resigned as director of the standards department of the Durant Motor Co., Elizabeth, N. J., to become affiliated with the Edward G. Budd Mfg. Co. as works manager of its Detroit division.

(Continued on next left-hand page)

Personal Notes of the Members

Continued

L. H. Hazard now holds the position of superintendent for the Rock Island Mfg. Co., of Rock Island, Ill. Prior to this connection, Mr. Hazard was works manager of the O. E. Szekely Corp., at Holland, Mich.

F. E. Hoffman, formerly inspector of airplanes and engines at the Atlantic Aircraft Corp., Hasbrouck Heights, N. J., has accepted a position with the General Airplane Corp., of Buffalo.

Marion W. Hughes, who has been a student in mechanical engineering at Ohio State University, recently became associated with the Landis Machine Co., of Waynesboro, Pa., in a designing capacity.

Everett U. Irish, having completed his engineering course in Swarthmore College, Pa., is now serving the International Motor Co., located in Allentown, Pa., as an apprentice engineer.

Chester C. Jackman, a former employe of the Apollo Magneto Corp., lately joined the engineering staff of the Rajah Co. of Bloomfield, N. J.

Leon J. Jurzek, of the Ford Motor Co., has been promoted from his former position of factory manager in the lamp plant, to that of superintendent of aircraft production.

Thomas J. Kiely, associated with the automotive division of the American Bosch Magneto Corp., of Springfield, Mass., has been promoted from assistant chief draftsman to chief draftsman.

Alfred L. Kiewit, a graduate this year of the college of engineering, Ohio State University, has been made test engineer at the Columbia power station of the Union Gas & Electric Co., of Cincinnati.

John A. Kraus, for the last four years sales engineer in the eastern district for Hercules Motors Corp., of Canton, Ohio, is no longer serving in this capacity. His future plans have not been announced.

Albert B. Kyle, formerly service superintendent of the W. P. Herbert Co., of Los Angeles, now owns and operates the D & D Garage, in the same city.

Charles H. Lawlor is now engaged in experimental work for the Buda Co., of Harvey, Ill. He was previously a student in mechanical engineering at the University of Illinois.

E. L. Ludvigsen recently established a connection with the Fuller & Sons Mfg. Co., of Kalamazoo, Mich., where he will assume the duties of sales engineer. Prior to accepting this position, Mr. Ludvigsen served as foreman of inspection for the White Motor Co., of Cleveland.

Maxwell F. MacNally has been made manager of the survey and engineering department of the RE-BO Co., Inc., Syracuse, N. Y. Previous to this appointment Mr. MacNally was sales engineer for the S.K.F. Industries, Inc., located at Buffalo.

Robertson Matthews has announced his intention of following research and development engineering work independently for a time. He was formerly identified with the research laboratories of the Detroit Edison Co.

A. L. Morse, formerly aeronautical engineer for the Atlantic Aircraft Corp. at Hasbrouck Heights, N. J., is now research engineer for the General Airplanes Corp., of Buffalo.

Otto G. Muller has been transferred to the Plainfield, N. J., branch of the International Motor Co. This change does not affect Mr. Muller's position as a member of the engineering staff.

Lieut. Erik H. Nelson recently established a connection with the Boeing Airplane Co., of Seattle, Wash. He was previously employed by the Curtiss Aeroplane & Motor Corp., at Buffalo.

(Continued on next left-hand page)

Personal Notes of the Members

Concluded

Pierre B. Pendill, now sales engineer for the Hall-Scott Motor Car Co., of Berkeley, Cal., formerly served the A. C. F. Motors Co., of San Francisco, in a similar capacity.

W. H. Ragsdale, until lately experimental engineer for the A. C. Spark Plug Co., Flint, Mich., has accepted a similar position with the Lycoming Mfg. Co., at Williamsport, Pa.

M. Sasaki, a former student at the Massachusetts Institute of Technology, has established a connection with the Fairchild Caminez Engine Corp. at Farmingdale, N. Y. Mr. Sasaki's new duties will consist of test engineering.

Alex K. Schaap, Jr., recently acquired full ownership of R. L. Schaap, Brooklyn, N. Y. He previously held a part interest in the concern.

E. F. Schroeder recently became cadet engineer for the Corn Products Refining Co., Argo, Ill. He was a former student at the University of Illinois.

Charles R. Short, former consulting engineer with headquarters in Detroit, has established a connection with the Moraine Products Co., Dayton, Ohio. He will act as consulting research engineer.

S. J. Shure, after taking an engineering course at M. I. T., lately became identified with the Shure Brothers Co. in Chicago.

Warren H. Smith has accepted the position of draftsman with the Four Wheel Drive Auto Co., Clintonville, Wis., after attending Purdue University.

W. S. Stockton, who recently resigned as chassis engineer with the Willys-Overland Co., has assumed the duties of sales engineer for the Bendix Brake Corp., of South Bend, Ind.

Adam K. Stricker, Jr., a former student of mechanical engineering at the Massachusetts Institute of Technology, will pursue research work as a junior engineer of the General Motors Corp., in Detroit.

David W. Thompson has entered upon the student course given by the International Harvester Co., Chicago. Prior to taking this course, Mr. Thompson studied engineering at the University of Wisconsin.

Norman N. Tilley, associated with the Materiel Division of the United States Army Air Corps, Wright Field, Dayton, Ohio, has been promoted from associate mechanical engineer to mechanical engineer.

Capt. Edwin S. Van Deusen, upon his recent completion of a course in highway engineering and transport at the University of Michigan, enlisted in the Quartermaster Corps of the United States Army and assumed charge of the Quartermaster Corps Motor Procurement Planning office, in Detroit.

Hubert Walker lately severed his connection as chassis engineer with the American Car & Foundry Motors Co. to accept the post of assistant chief engineer of the production and development division of the American LaFrance & Foamite Corp., of Elmira, N. Y.

John H. Weller, who was until recently general manager of the Acme Motor Truck Co., at Cadillac, Mich., now holds the position of factory manager of Sargent & Co., located at New Haven, Conn.

P. F. Williams is now engaged in experimental installation for the Bendix Brake Co. of South Bend, Ind. He previously attended Purdue University.

Donald K. Wilson, formerly assistant superintendent of transportation with the Utica Gas & Electric Co., Utica, N. Y., has been promoted to superintendent of transportation for the company.

J. M. Wilson, affiliated with the Le Baron Detroit Co., has been promoted from draftsman to designer. Mr. Wilson is also designer for the Briggs Mfg. Co., also located in Detroit.

Charles A. Winslow, who until lately was a consultant in engineering, with offices at Vallejo, Cal., has accepted the position of research engineer with the Sheet Steel Products Co., of Michigan City, Ind.


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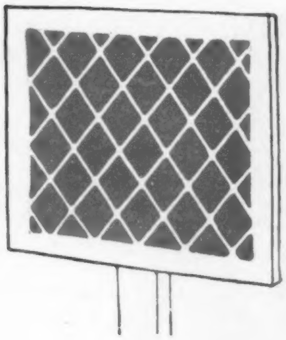

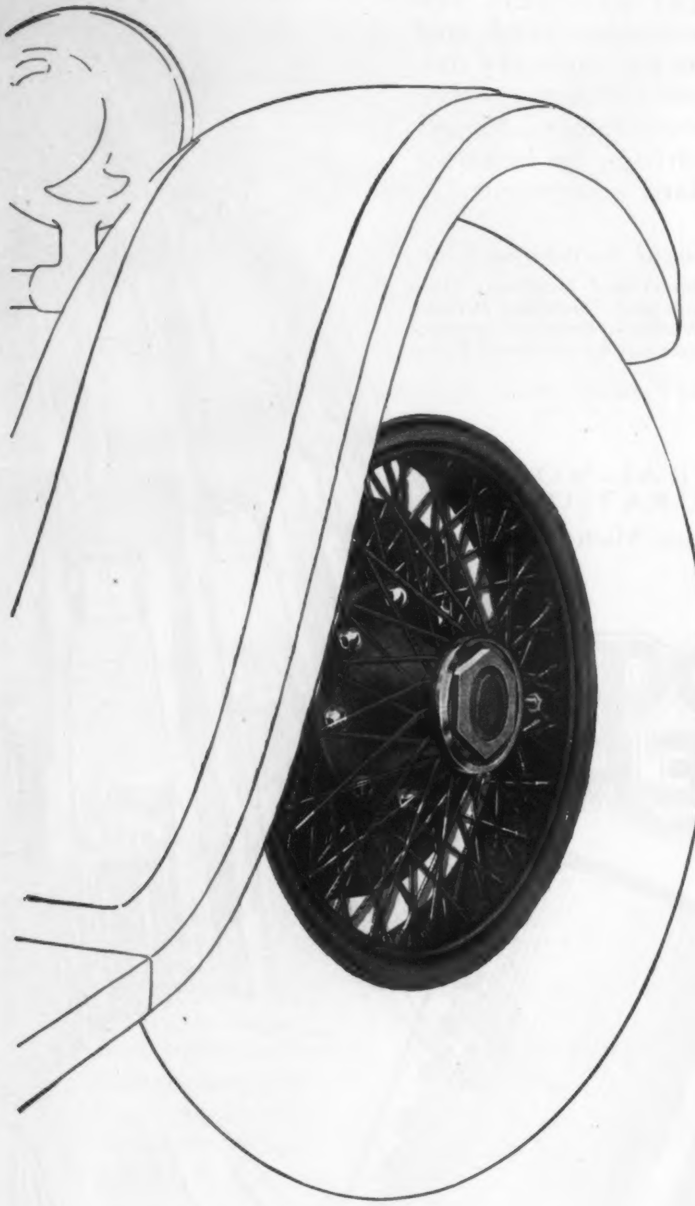

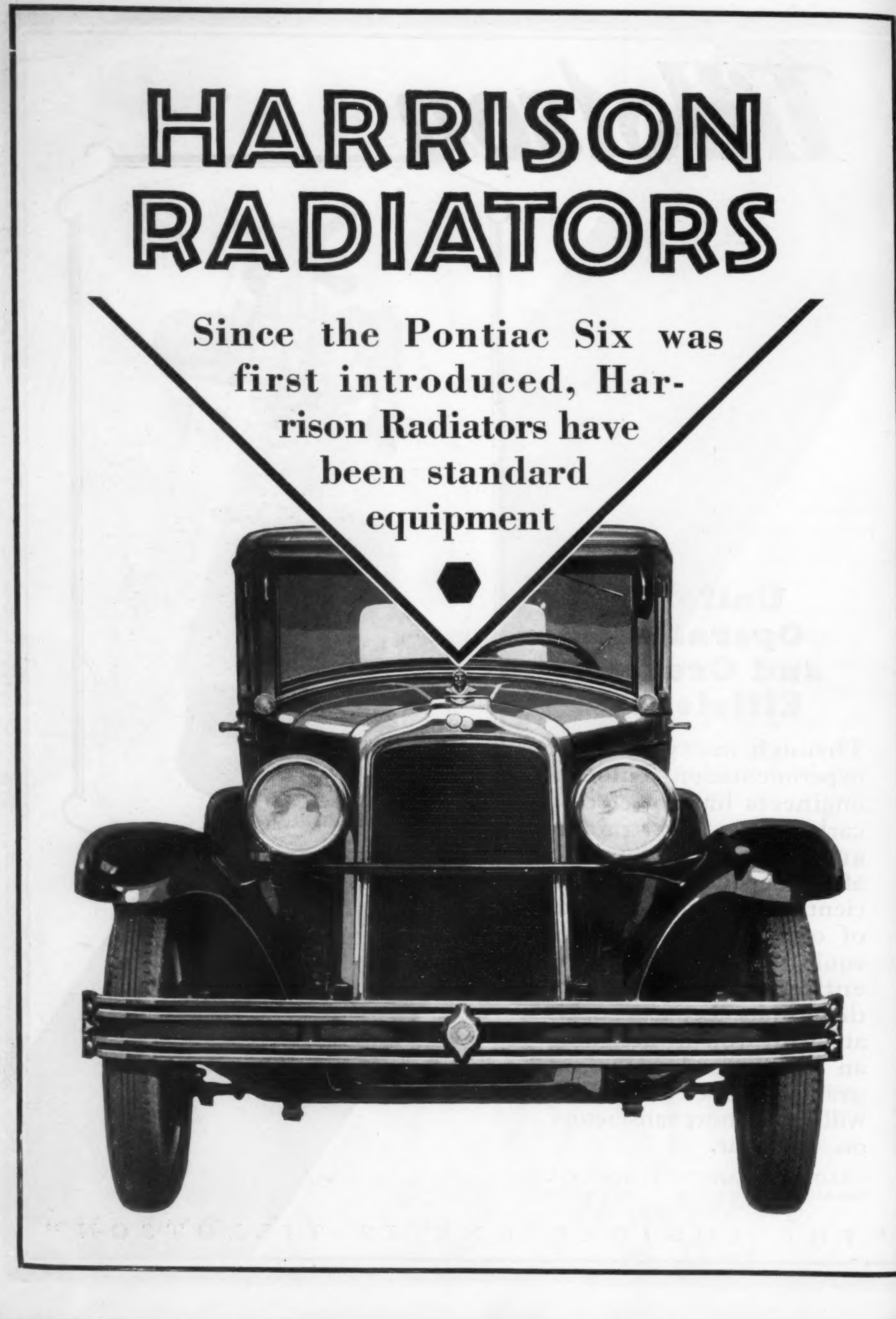
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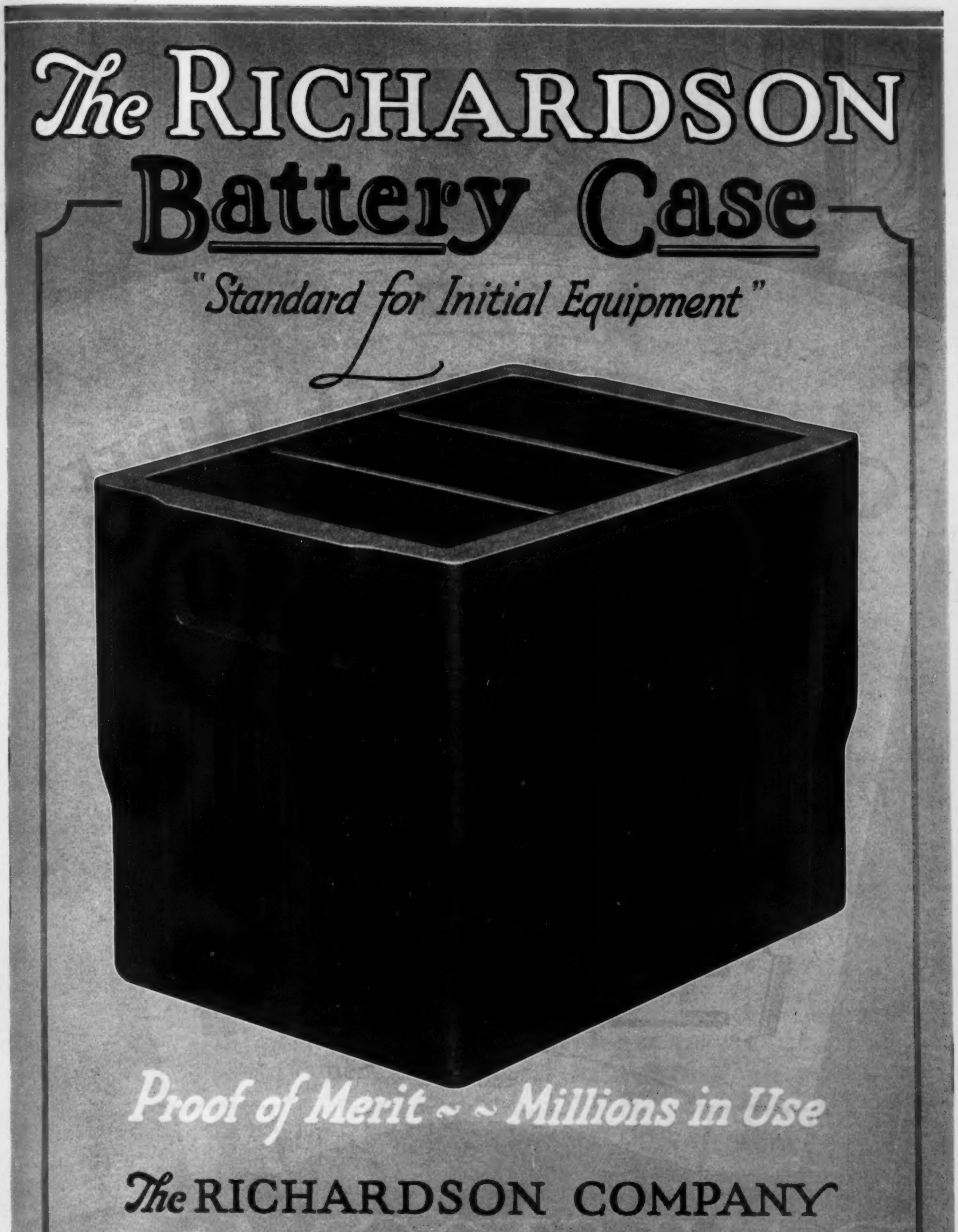
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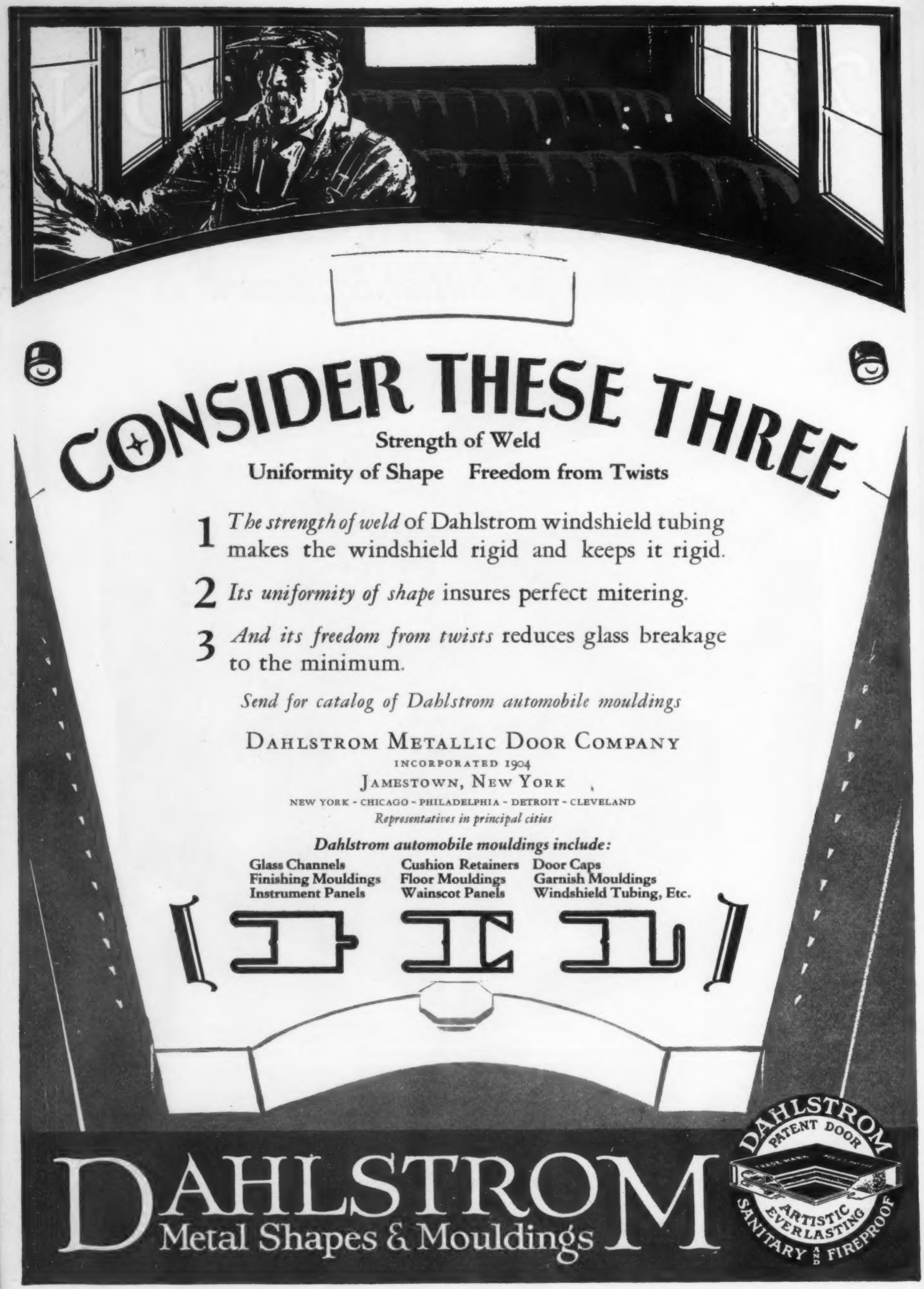
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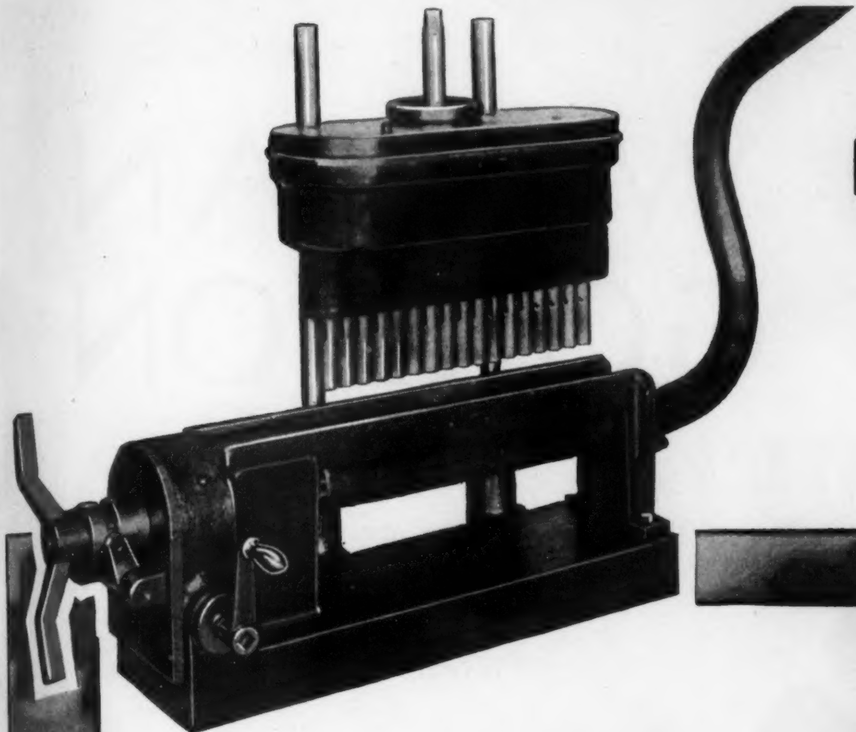

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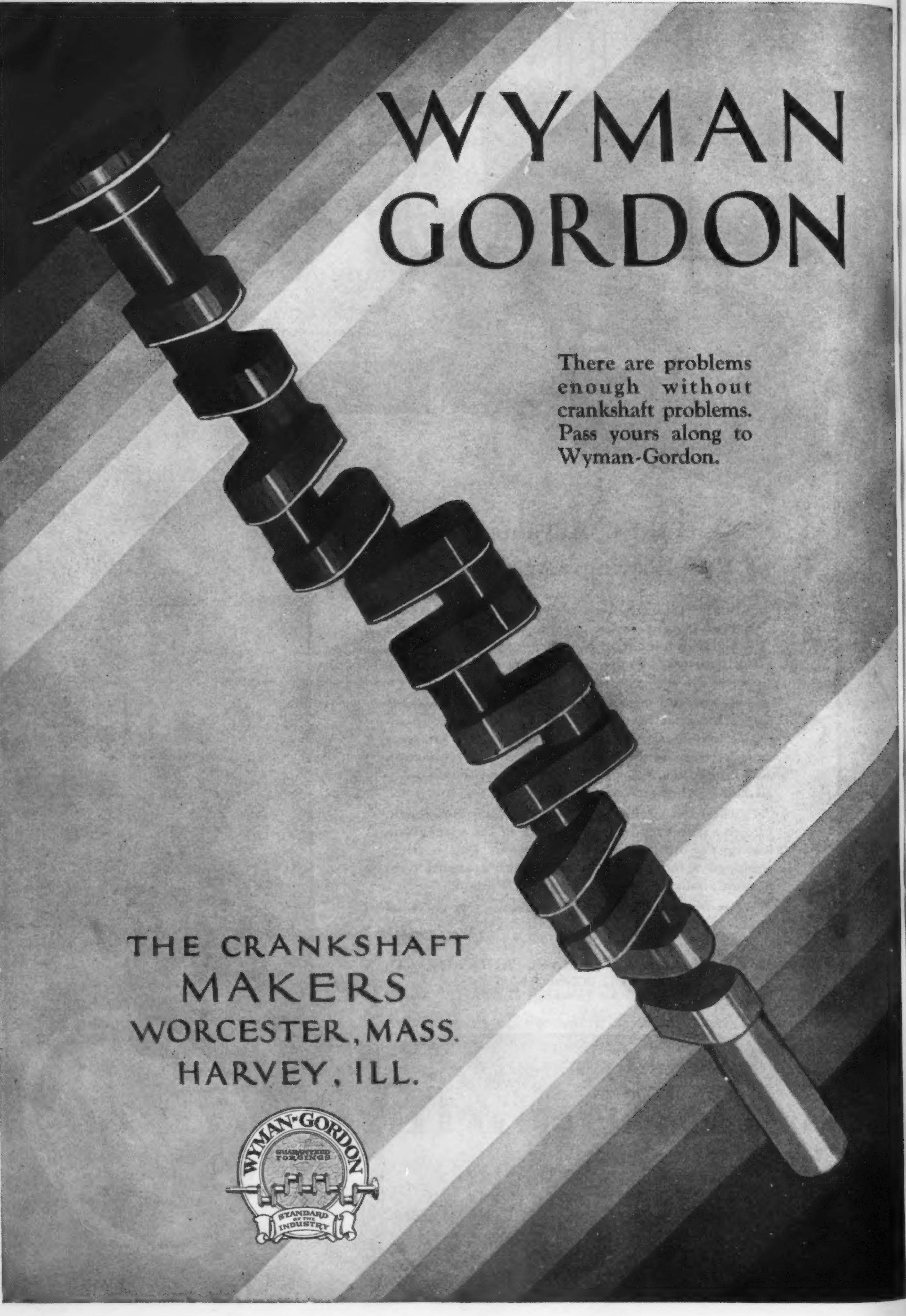
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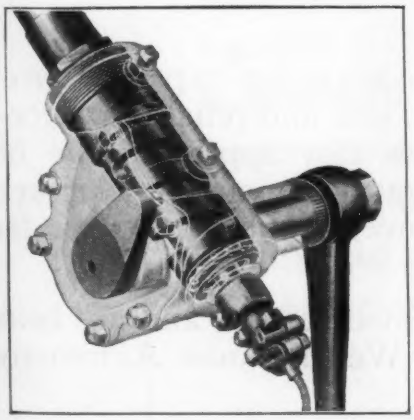

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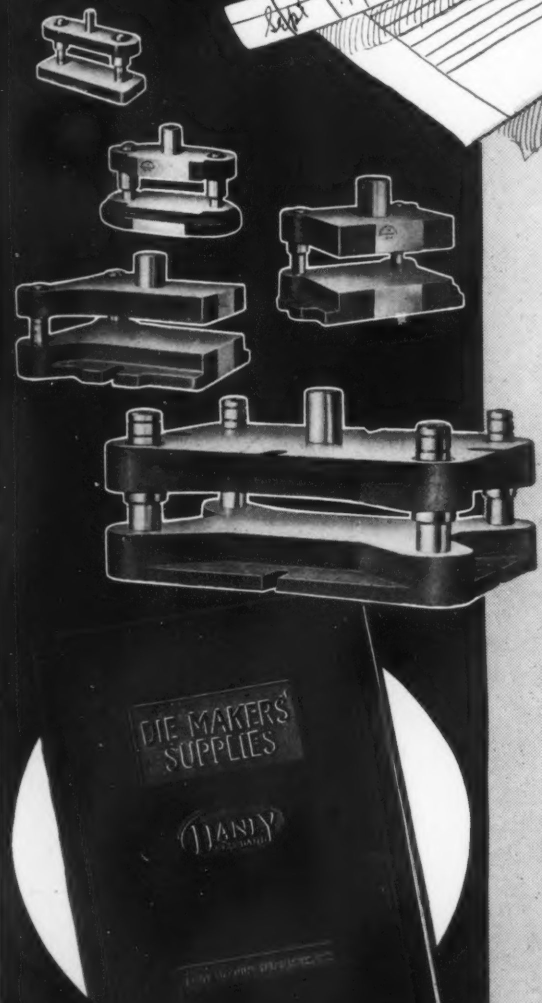

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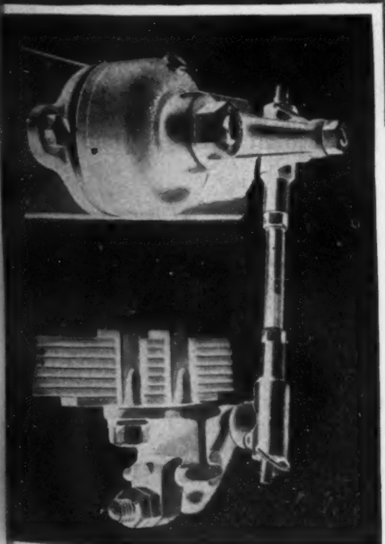

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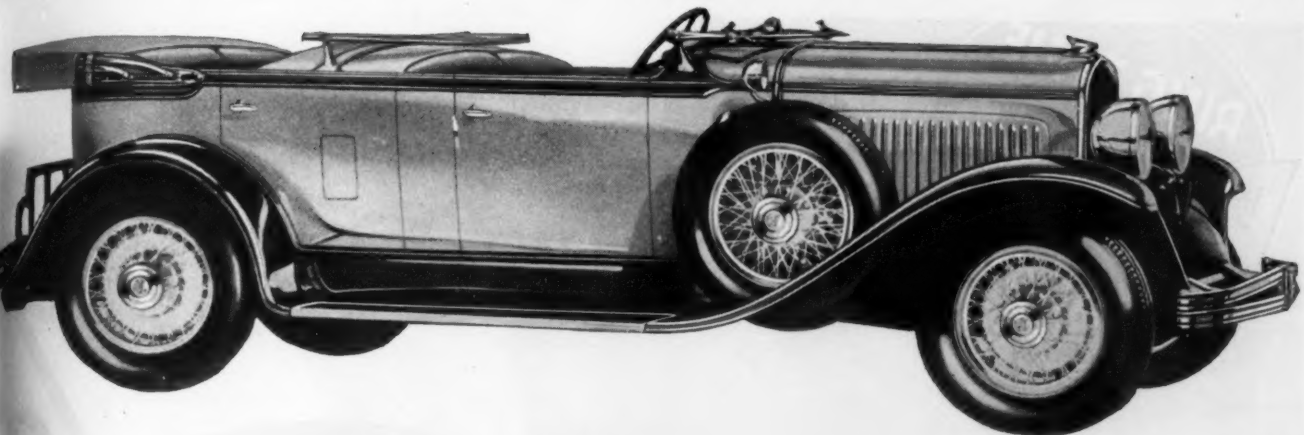

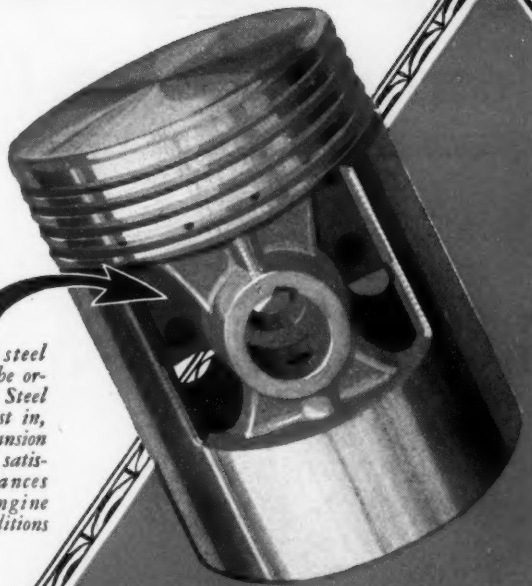

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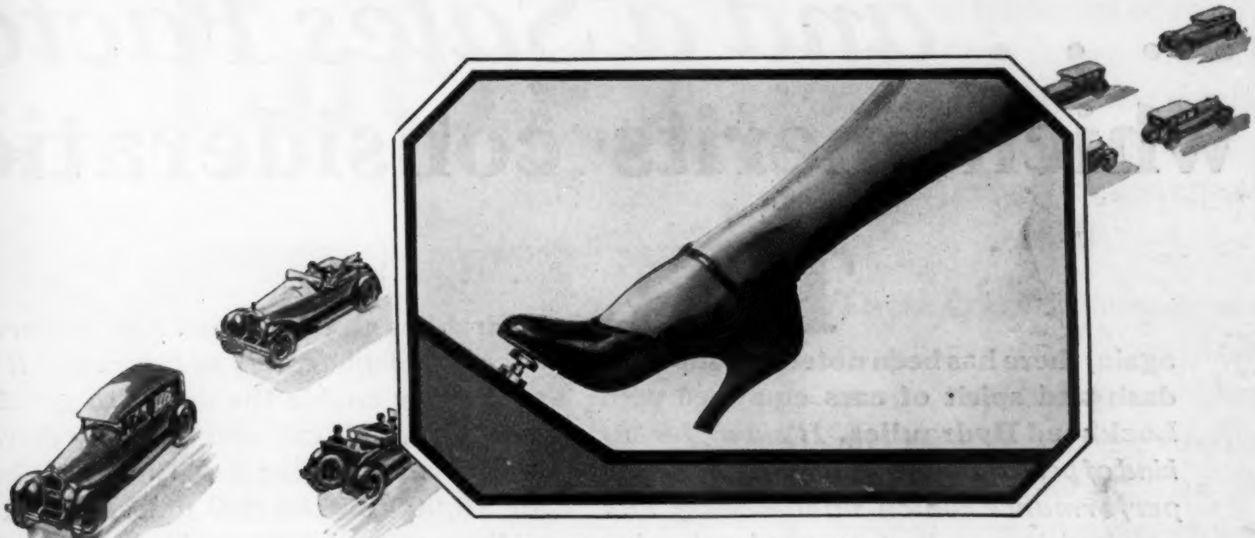

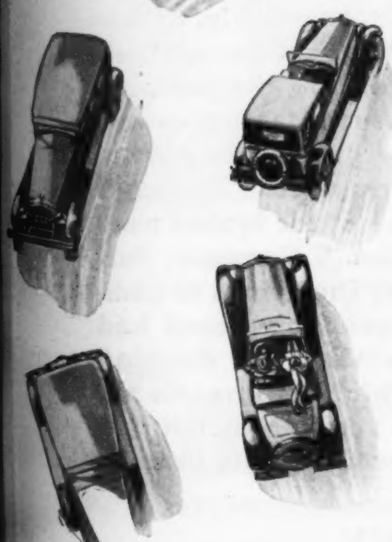

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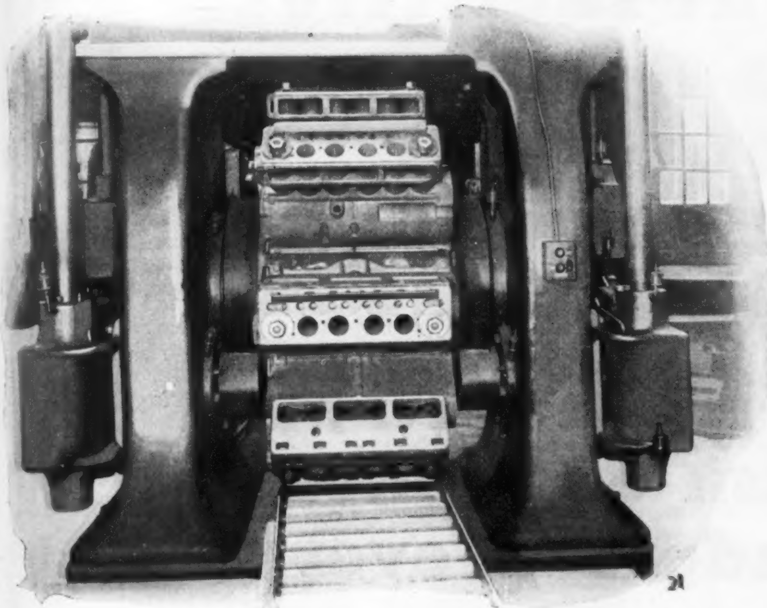
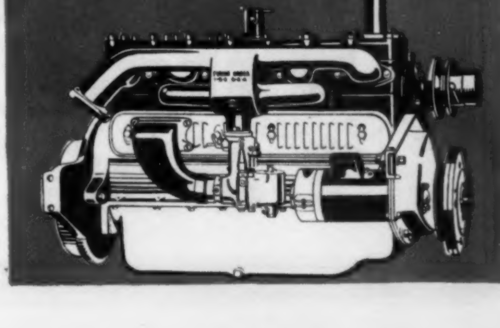
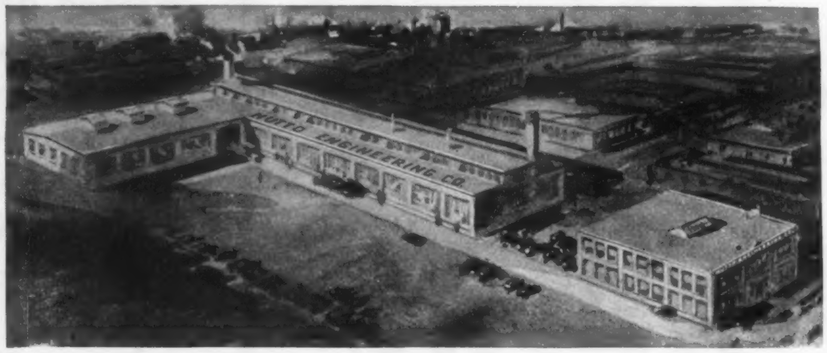
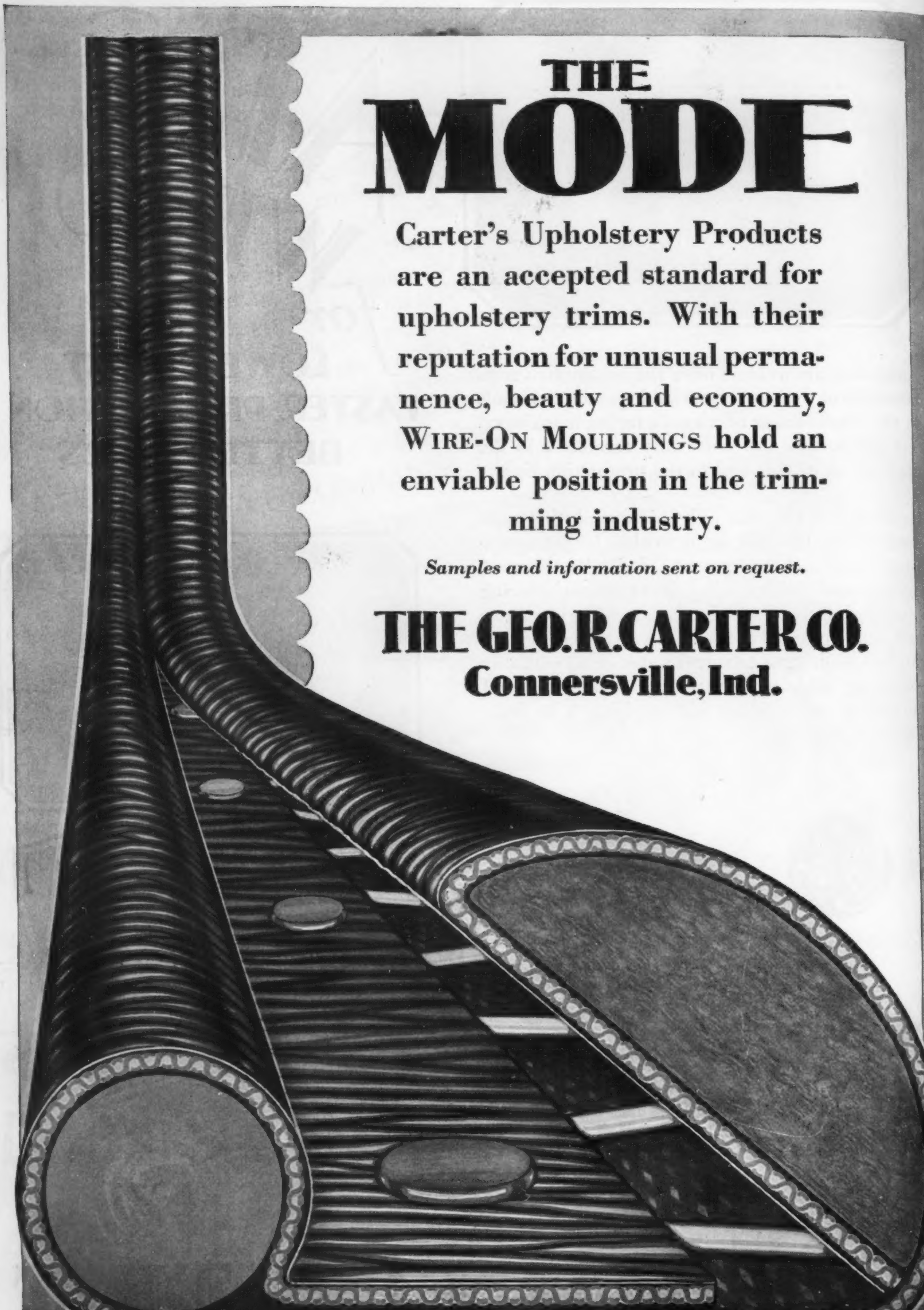
Starting, Lighting & Ignition



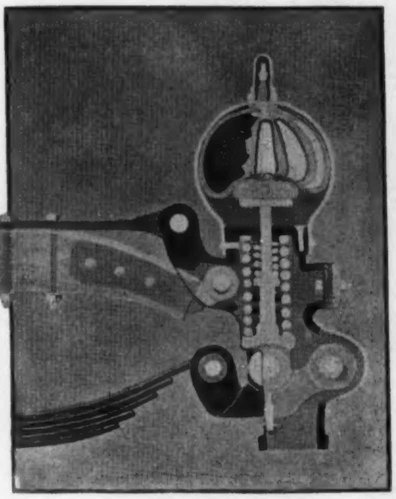





THE
MODE
Carter's Upholstery Products are an accepted standard for upholstery trims. With their reputation for unusual permanence, beauty and economy, WIRE-ON MOULDINGS hold an enviable position in the trimming industry.
Samples and information sent on request.
THE GEO. R. CARTER CO.
Connersville, Ind.

SPRINGS
-helped them come
-helped them go
B.G.R. INC.
The Sign of Better Craftsmanship in Springs
UNDERWOOD & UNDERWOOD
Automobiles at Mundelein, Ill. June 1926
SPECIALISTS IN VALVE AND CLUTCH SPRINGS
BARNES - GIBSON - RAYMOND
INCORPORATED
DETROIT MICH

Every Mile a Pleasure With Hofmann Frictionless Air Springs



(Patented)

THE Hofmann Frictionless Air Springs are now applicable on any pleasure car, truck or bus.

The illustration below shows their application on the present Model A Ford car, which allows the same relation between axle and frame to be maintained and yet adds 2¼″ more amplitude in the spring system, allowing this 2¼″ additional travel on one end of the spring before affecting the car frame of pleasure cars.

A Model A Ford car equipped with Hofmann Air Springs was driven over a 20 mile test section of road at a speed of 35 to 45 miles per hour, and by means of mechanical counters the number of swings between the front axle and the frame of the car were recorded, and also the number of movements of the Air Spring mechanism.

With the Hofmann Air Springs in operation 917 swings of the front end of the car were recorded on this 20 mile test run, and 456 movements of the Air Spring mechanism. The run was then repeated with the Air Spring mechanism locked and 1916 swings or periods of the car were recorded, thus showing the marked beneficial effect of the Hofmann Air Springs.

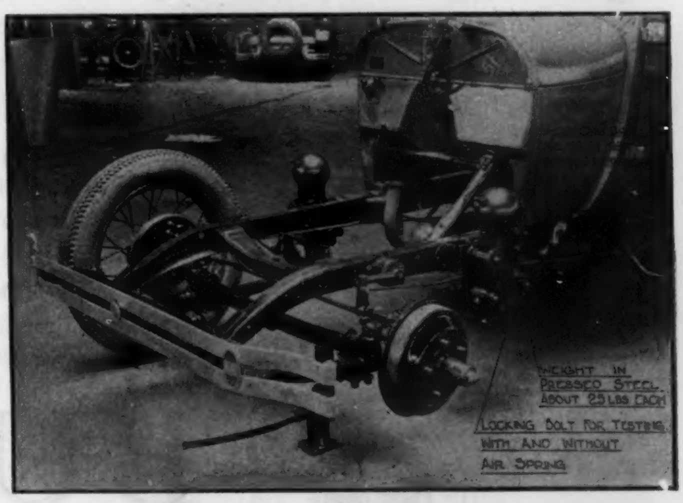
This apparatus is not a snubber.

We take all the teeter out of cars equipped with balloon tires.

Charles Faroux, the celebrated French automotive engineer, stated sixteen or seventeen years ago, that the automobiles of the future would have long flexible leaf springs and auxiliary air springs, together with snubbers, to prevent the swings at high speeds or over rough roads.

This Frictionless Air Spring was invented by Josef Hofmann, one of the world's most celebrated pianists.

The Stevens Products Co., Inc.
Lowell, Mass.



FOR STANDARD EQUIPMENT

In 1907 . . .

"HUH!" SAYS CABBIE TERENCE (EXTREME LEFT), "THEM GAS BUGGIES IS ALL RIGHT FOR NUTS TO PLAY WIT', BUT WHEN PEOPLE WANTS TO GO PLACES DEY WANTS A HORSE." "I HOPE YOU'RE RIGHT, TERENCE," SAYS GLOOMY GUS (CENTER). 'TWAS WITH SUCH MANIFESTATIONS OF CORDIALITY AND OPTIMISM THE CAB RANK WELCOMED THE FIRST GASOLINE TAXI (EXTREME RIGHT) IN 1907.

TODAY the tick of the taxi-meter is heard throughout the land. At almost any curb, by a twitch of the finger, you can summon a slice of the rainbow on wheels.

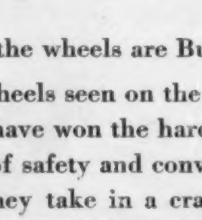
Most likely the wheels are Budd-Michelins.

For these wheels seen on the smartest cars of Europe and America have won the hard-headed taxi companies on the basis of safety and convenience. No matter how stiff a blow they take in a crash, they cannot shatter or collapse. If a Budd-Michelin bends, the spare fifth wheel takes its place. For $3 or so the damaged wheel can be fixed. The same little fracas would smash a wooden wheel, tie up the car for hours and cost the price of a tow and a brand new wheel.

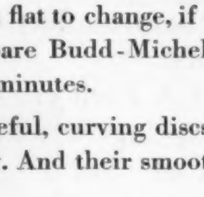
That same convenient extra wheel simplifies tire-shifting. When there's a flat to change, if comes off with the wheel—and the spare Budd-Michelin goes on. It needn't take over four minutes.

Budd-Michelins' graceful, curving discs dress up the smart, trim car of today. And their smooth surfaces are easy to wipe or wash.

The man who can say all this about the wheels on the car he's selling, knows how often "Budd-Michelin equipped" closes a sale for him.

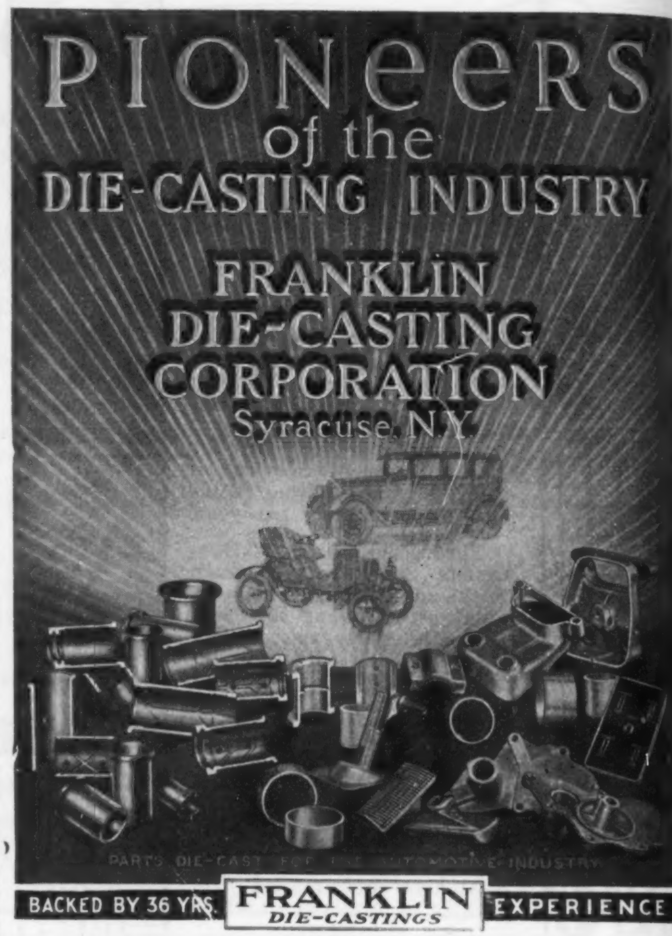


BUDD



WHEEL COMPANY, DETROIT

Also makers of the Budd Interchangeable Wire Wheel and Budd Dual Wheel


PIONeeRS
of the
DIE-CASTING INDUSTRY
FRANKLIN
DIE-CASTING
CORPORATION
Syracuse, N.Y.
PARTS DIE-CAST FOR THE AUTOMOTIVE INDUSTRY
BACKED BY 36 YRS. FRANKLIN DIE-CASTINGS EXPERIENCE


HOOVER
America's Foremost Ball Plant
Producing
A complete line of
—BALLS—
BALL-BEARINGS
and
ROLLER BEARINGS
Send us your Blue Prints.

Car Owners

appreciate this "trouble-proof" shock absorber. It is the only shock absorber *unconditionally guaranteed for the life of the car against strap and spring breakage.*

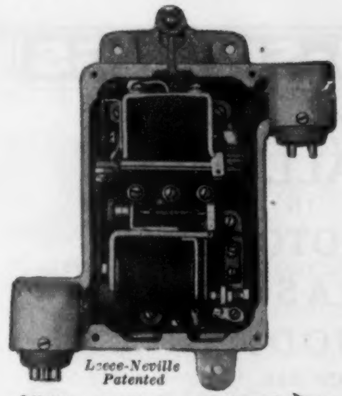
For Light Cars $22^{00}

For Large Cars $30^{00}

CHANSON

SHOCK ABSORBERS

Manufactured by CHANSON DIVISION
Illinois Iron & Bolt Co., Carpentersville, Illinois



Leece-Neville Patented

Battery cannot be over-charged. The battery is charged only at the correct rate for its state of charge.
Battery will operate longer without requiring replenishing of electrolyte.
Life of battery greatly prolonged.
Lights can be operated direct from generator.
Loose connections will not cause lamp bulbs to burn out.
Makes most economical generator system.
Any Leece-Neville Voltage Regulated Generator can be used without battery.
Lamp life greatly prolonged.
Motor coaches fitted with Leece-Neville voltage regulated generators provide passengers with satisfactory illumination and safe transportation.

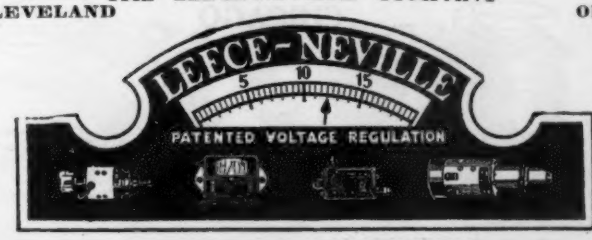
Isn't It Just Common Sense to Keep Your Expense Sheet As Low As Possible ?

MINIMIZE your electrical maintenance with Leece-Neville Voltage Regulation.

Leece-Neville voltage regulation equipment is built to a *quality standard* and not to a price. It is a guarantee of a *stability and service* such as every successful operator demands.

Specify Leece-Neville on your next truck . . . keep down that expense sheet.

THE LEECE-NEVILLE COMPANY
CLEVELAND OHIO



THIS Company has been engaged in the production of camshafts exclusively since its inception in 1916 and our organization is composed of men who have become specialists in the operation they are asked to perform in machining and heat-treating them. Equipment developed in this plant makes it possible to turn out experimental work rapidly. Twenty-four hour deliveries after receipt of order frequently being accomplished.

We are in a position to render unusually accurate service in cam production, checking valve lifts in .0001".

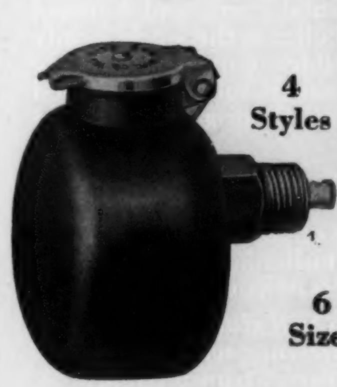
A system of double checking pyrometer and test bars insure heat-treating accuracies.

Many of the larger manufacturers are now finding it to their advantage to abandon their camshaft machining departments and let us take care of their production and experimental camshaft problems. We are always glad to assist anyone who is having difficulties with their camshafts.

L-O GORDON MANUFACTURING CO.

MUSKEGON, MICH.

Correct Chassis Lubrication



4 Styles

6 Sizes

Gits Chassis Oilers
are constantly replacing grease fittings because they
DO IT BETTER

Gits Bros. Mfg. Co., 1940 S. Kilbourn, Chicago

Los Angeles Aeronautic Meeting—Sept. 11 and 12

For details of Meeting, which will be reported in the October Issue of the S. A. E. Journal, see page 225 of this issue.

Attention is directed to announcement regarding Part I of the 1927 Transactions on p. 14.

MEMBERS' PROFESSIONAL CARDS

INDEX TO ADVERTISERS' PRODUCTS

(*Continued on page 108*)

Manufacturers of Products Conforming to S.A.E. Specifications

Advertisers whose products conform to S.A.E. specifications are also listed in the S.A.E. Handbook List of Manufacturers, on page 560, of the 1928 issue of the Handbook.

The addresses of companies listed in this index can be obtained from their current advertisements indexed on page 114.

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Castings, Die-Cast
Franklin Die-Casting Corporation

Castings, Grey Iron
Link-Belt Co.

Castings, Malleable Iron
Link-Belt Co.
Timken Roller Bearing Co.

Castings, Steel
Clark Equipment Co.
Link-Belt Co.

Castings, Tin Alloy
Federal-Mogul Corporation

Chains, Block
Link-Belt Co.
Morse Chain Co.
Whitney Mfg. Co.

Chains, Roller
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Whitney Mfg. Co.

Chains, Silent
Link-Belt Co.
Morse Chain Co.
Whitney Mfg. Co.

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Unit Corporation of America

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General Electric Co.
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General Plastics, Inc.

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Cups, Priming
Dole Valve Co.

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Whitney Mfg. Co.

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Oakite Products, Inc.

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Danly Machine Specialties, Inc.

Die Sets
Danly Machine Specialties, Inc.

Differentials
New Process Gear Co., Inc.

Door-Caps
Dahlstrom Metallic Door Co.

Drills, High-Speed
Clark Equipment Co.

Drop-Forgings
Bethlehem Steel Co.
Park Drop Forge Co.
Spicer Mfg. Corporation
Union Switch & Signal Co.
Wyman-Gordon Co.

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Shore Instrument & Mfg. Co.

Dynamometers, Chassis
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Dynamometers, Engine
General Electric Co.

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Wisconsin Motor Co.

Engines
Continental Motors Corporation
Waukesha Motor Co.
Wisconsin Motor Co.

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General Electric Co.

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Russell Mfg. Co.

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Detroit Carrier & Mfg. Co.

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Motor Wheel Corporation

Felt
American Felt Co.

Filters, Gasoline
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Filters, Oil
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Arco Co.

Flanges, Hub
Bossert Corporation

Floors, Metal
Dahlstrom Metallic Door Co.

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Aluminum Co. of America

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Scovill Mfg. Co.

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Akron-Selle Co.
Nagel Electric Co., Inc.

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Schrader's Son, Inc., A.

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Unit Corporation of America

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Link-Belt Co.

Gears, Composition
General Electric Co.

Gears, Differential
New Process Gear Co., Inc.

Gears, Fibre
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Gears, Reduction
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Waukesha Motor Co.

Gears, Spur
Link-Belt Co.

Gears, Steering
Ross Gear & Tool Co.
Warner Corporation

Gears, Timing
General Electric Co.

Gears, Transmission
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Wyman-Gordon Co.

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Electric Auto-Lite Co.
General Electric Co.
Leece-Neville Co.
North East Electric Co.

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Carter Co., George R.

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Aetna Rubber Co.

Glycerine, Radiator
Glycerine Producers' Association

Governors
Kingston Products Corporation

Grinding Compounds
Oakite Products, Inc.

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North East Electric Co.

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Insulation, Electric
Bakelite Corporation
General Electric Co.

Insulation, Molded
Bakelite Corporation

Joints, Ball-and-Socket
Thompson Products, Inc.

(Continued on page 110)


Economy
IN COSTS AND SERVICE
LONG life and ability to stand up under the most severe service are the outstanding characteristics of FEDERAL RADIAL BALL BEARINGS. That is why well-informed engineers invariably select "FEDERALS" in preference to other bearings. Sturdy reliability and inherent quality can only mean greater economy for manufacturer as well as user.
We shall be pleased to forward samples, quotations and complete information to those interested
Send for Data Sheets
THE FEDERAL BEARINGS CO., Inc.
Poughkeepsie, New York
Detroit Sales Office: 1121 Book Building
FEDERAL
1308
FEDERAL
RADIAL BALL BEARINGS

INDEX TO ADVERTISERS' PRODUCTS

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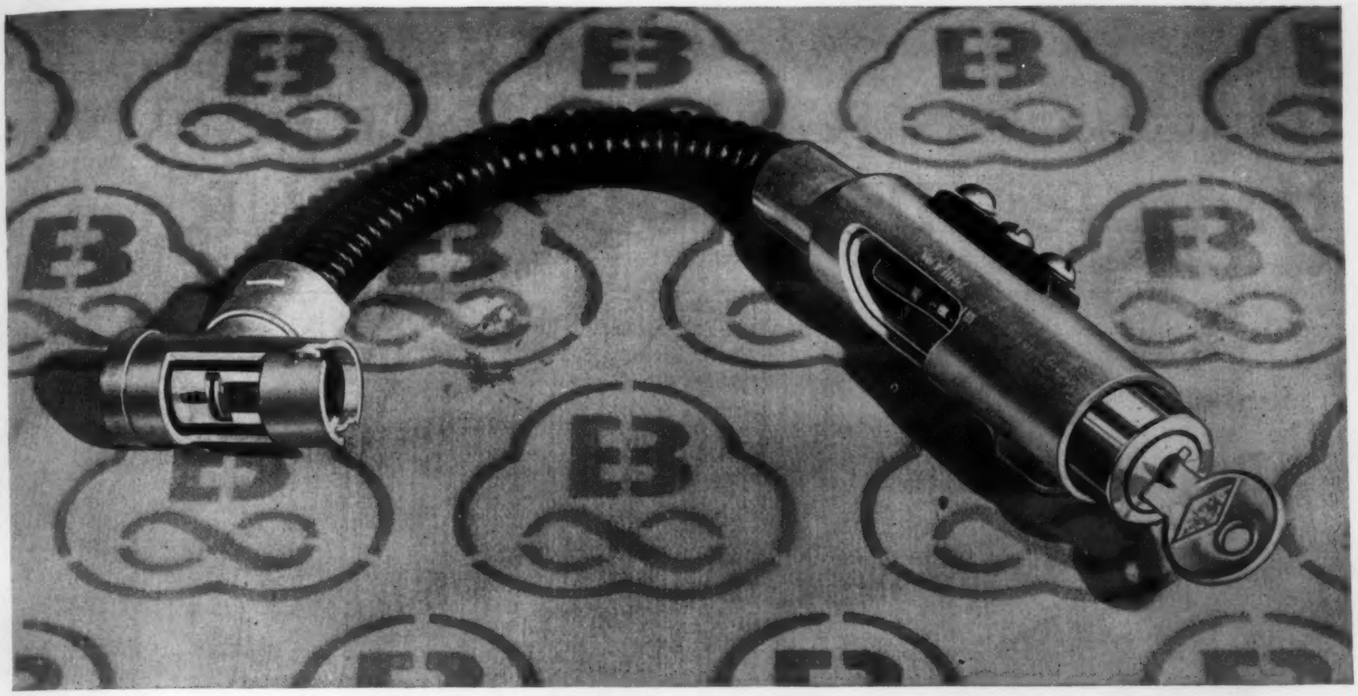
INDEX TO ADVERTISERS' PRODUCTS

INDEX TO ADVERTISERS

The Index to Advertisers' Products is given on pages 106, 108, 110, and 11[illegible]



Coincidental Electrolock, with metal housings cut away to show parts of Bakelite Materials. Mitchell Specialty Co., Philadelphia, Manufacturers.

Bakelite Materials are used because of their uniformity and unusual combination of properties

To be adopted as standard equipment for the large majority of motor cars in every price class, is an endorsement won by few devices. To attain this position the Electrolock coincidental ignition switch and lock had to be made of time proven materials.

The insulation needs of the Electrolock are being met by Bakelite Materials. In the switch end there is a heavy Bakelite Molded terminal block with molded in contacts, and a Bakelite Laminated punching insulates the make and break mechanism. At the other end of the device is a tubular insulation part of Bakelite Molded.

Economical production of the Bakelite Molded parts is secured through using a nineteen cavity mold for one part and a sixteen cavity mold for the other.

Bakelite Engineering Service

Intimate knowledge of thousands of varied applications of Bakelite Materials combined with eighteen years' experience in the development of phenol resinoids for industrial uses provides a valuable background for the cooperation offered by our engineers and research laboratories.

BAKELITE CORPORATION
247 Park Avenue, New York, N. Y. Chicago Office, 635 West 22nd Street
BAKELITE CORPORATION OF CANADA, LTD., 163 Dufferin Street, Toronto, Ont.

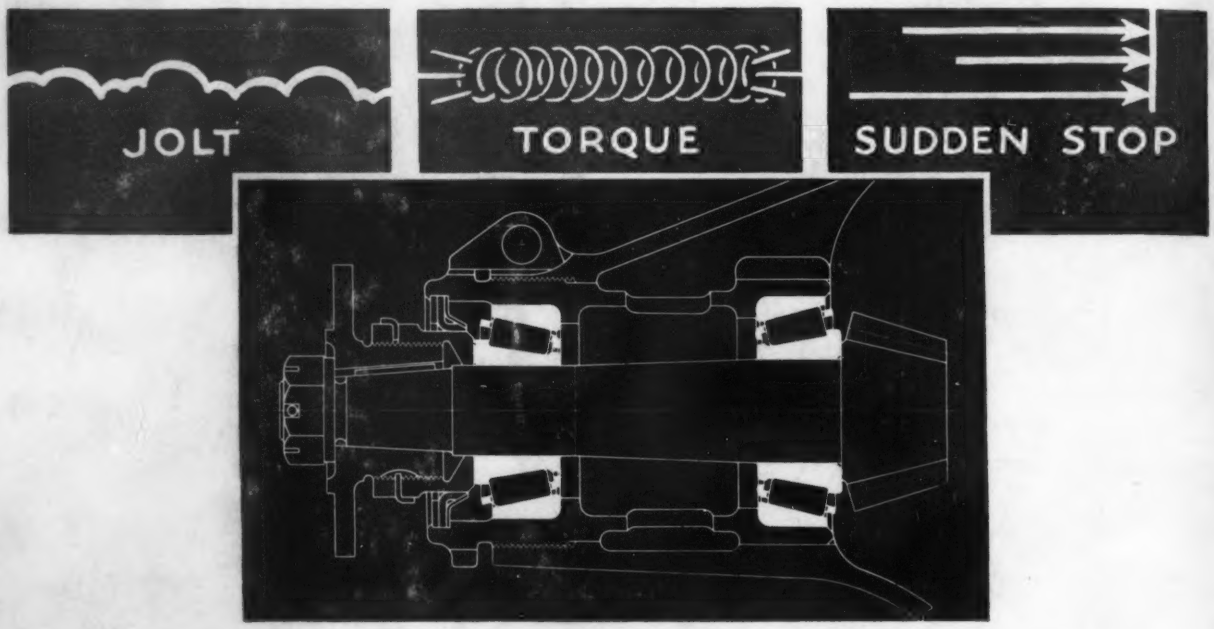
BAKELITE

REGISTERED U. S. PAT. OFF.

THE MATERIAL OF A THOUSAND USES

"The registered Trade Mark and Symbol shown above may be used only on products made from materials manufactured by Bakelite Corporation Under the capital "B" is the numerical sign for infinity, or unlimited quantity It symbolizes the infinite number of present and future uses of Bakelite Corporation's products."

TO SERVE··TO SAVE··TO SURVIVE



A thousand devils of travel—thrust and tear at the pinion drive—only the best bearings are good enough to serve—to save—to survive.

Perhaps this accounts for the manner in which sentiment swings unmistakably to Timken.

For Timken Bearings are *more* than anti-friction. They are fully thrust-radial, provide greater load carrying capacity that sets at defiance the thrust and shock from any and all directions. *Extra* miles of smooth, quiet, trouble-free travel are assured only by Timken tapered construction, Timken *POSITIVELY ALIGNED ROLLS,* and Timken-made electric steel.

THE TIMKEN ROLLER BEARING CO., CANTON, OHIO

TIMKEN *Tapered Roller* **BEARINGS**